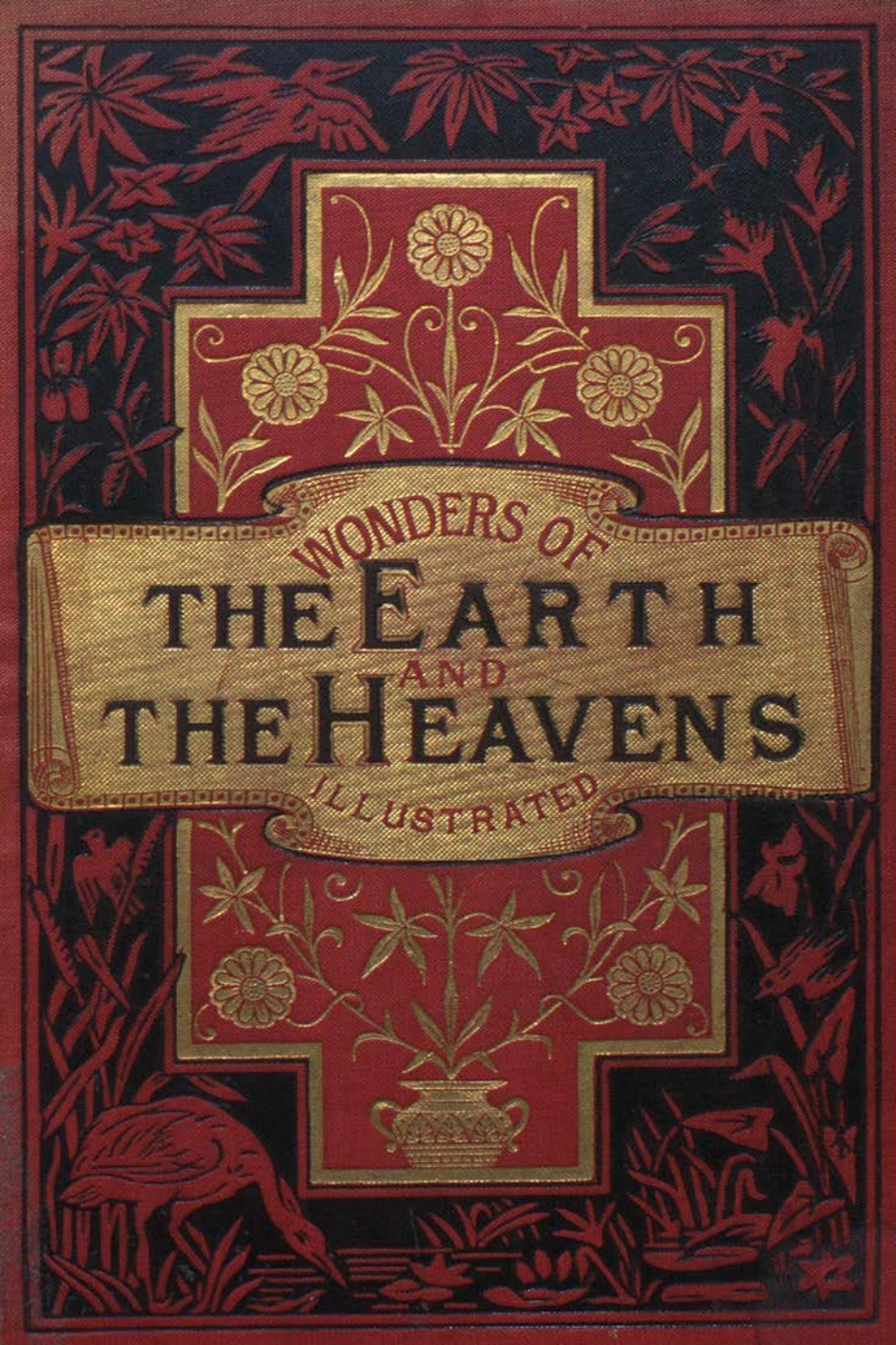

WONDERS OF
THE EARTH
AND
THE HEAVENS
ILLUSTRATED

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To dear Marcus

Wishing him many happy
returns of the day
from Louis F. Lewin
April 2nd/96

WONDERS OF THE EARTH

AND

THE HEAVENS.

BEING

A POPULAR ACCOUNT OF

THE FORCES OF NATURE, GRAVITY, THE BAROMETER AND AIR-PUMP, AND ALSO OF ASTRONOMICAL APPARATUS, THE SOLAR SYSTEM, MODES OF COMPUTING TIME, THE PLANETS, COMETS, ECLIPSES, AND THE CONSTELLATIONS.



Profusely Illustrated.

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WONDERS OF EARTH, AIR, AND WATER.

INTRODUCTION.

THERE are some people who go through life practically blind. Indeed, for many purposes they might just as well be blind. Of them it might with truth be said, that "seeing, they see not." To their eyes and perceptions the sun is just a hot, bright body, that warms us too much sometimes; sunset is simply the signal for lighting candles or gas, or for sitting idly, or groping awkwardly under the pretence of "blind man's holiday;" a thunderstorm is a terrible nuisance, especially if, dressed for a visit, they happen to be caught in one; the star-spangled heavens afford a very pretty excuse for a walk, during which they never so much as lift their eyes to the splendid vision; and life's pageant is but a round of duties or parties, which certainly do not lift their thoughts heavenward.

How extraordinary and forceful is the contrast between this state of mind and that person's who possesses the seeing eye, the hearing ear. To such, among whom we venture to claim a place, the sun is a glorious orb of fire, emitting light and heat which are essential to the life of a world; sometimes dazzling us with its full radiance, often warming us and cheering our hearts after a winter's cold, ripening the harvest and embrowning the complexion; the leader, for us, of that continuous procession of brightness across our sky; now bold and ruddy at the beginning and close of his daily round, now pure

and white as he is seen higher in the sky; and anon showing, in the glories of sunset, the extraordinary effects which may be produced by simple light and cloud, with the varying distribution of vapour in the air. How can people be insensible to the charms of twilight, whether long drawn out or suddenly precipitated, the stillness of the air as the sun glides down, or the shrill whistle of the wind as the night storm rises, the graceful oscillation of the branches of trees, too often and too early shedding their leaves as they move? Even the dull leaden sky, the gentle, steady downpour of rain, have their own points of interest, which the lover of nature is not slow to find out; while the consequences of rain in the general refreshment of plants, the cleansing of the air and of the ground, the washing of houses, the filling of streams and rivers, are among the most delightful of natural phenomena. Only at one atmospheric effect, in producing which, however, man is a participator, do we not rejoice—namely, at the various kinds of fogs, laden with sooty particles from manufactories and locomotives, and all kinds of effluvia and germs of disease; and we look upon it as a pretty sharp lesson, with its attendant colds and rheumatisms and accidents, to sluggish mankind to mend his ways and consume his own smoke,—a lesson which will probably become more severe each year till we learn it.

But the thunderstorm,—how grand an event, how striking a study! The lightning flash in all its varieties, sheet and forked, near and far, blinding or merely glowing in the distance; the thunderclap, now sudden and sharp as a hammer blow, now slow and soft in sound, and gradually waxing to a climax of rattling peals, and dying away in the distance, and again seeming to shake houses to their foundations, and even to affect the solid earth with its violence; and the rain, so often

following with desperate energy, and keeping on with wonderful persistence, as if it would exhaust the fountains of heaven by its copious discharges; and finally the stillness, freshness, and cleanliness succeeding the storm,—all these are rich treasures of delight to the instructed mind, which sees in these wonders but a faint expression of the surpassing glories and powers which belong to the supreme Worker of all.

True it is that "the heavens declare the glory of God, and the firmament showeth His handiwork." The continual procession of spots of beauty, each differing in magnitude and brightness, is a constant reminder to us to look to things above. The thought that each of these bright stars is a sun, essentially similar to our own sun, and supplying light to a number of non-luminous planets circling round it, is overwhelming when we consider the vast multiplicity of suns and planets that must exist in the universe. And the stately moon moves with soft grace through the sky, fulfilling its appointed task with as much regularity as the enormously greater and brighter sun. Can the dull soul of man, woman, or child remain blind to these glories after once having the attention vividly awakened, or forget them in a base surrender to evil jealousies and struggles? How attractive to the thoughtful mind it should be to penetrate, if but a little way, into the mystery of the forces which thus surround us and influence our being!

But some will say, "Oh, but we can appreciate the beauties of nature without studying them in a book. It is so dry, what is said in books, compared to enjoying things." We are prepared to assert that what is found in books about nature need not be dry, and very often is not, and that some of the most entertaining of these accounts may be found in the following pages. Even should there be a little close attention demanded, in order

to understand some explanations, yet we maintain that this will be amply compensated by the great gain to our appreciation of nature which follows a closer acquaintance with the details. Does not a knowledge of the solar system, and the mode in which the planets revolve round the sun,—of the fact of the stars being so many suns at very great distances,—of the changes of day and night being produced by the revolution of the earth upon its axis, and the other wonders of astronomy, greatly enlarge the pleasure to be derived from their contemplation? Does not the reference of everything to its course, and the realisation of the orderliness of the complex arrangements of the universe, both increase our enjoyment of the results and raise our minds to the wonderful powers of the great First Cause of all?

The basis of a satisfactory examination of the powers of nature must be the understanding of the simple properties of the matter or substance of which they are composed. There are certain properties which are found to be common to all matter, of whatever composition; and when they are clearly grasped, we shall be equipped for a consideration of the differences between the properties of different kinds of matter. The familiar questions and answers, "What is matter? Never mind. What is mind? Never matter," contain a great deal of truth, although some people have asserted that mind is a product of matter, a sort of fruit produced by its workings. But they have made this rather as an assertion than as a subject of proof. Because our thinking is done in connection with the brain, they have suggested that no thinking can be done anywhere without a brain. It is really idle to waste time on such conjectures, when there is so much to be done in studying what we can understand.

Others have suggested that matter is a delusion of the

senses, and that we only imagine we see or feel different objects. They say that matter has no real existence, and that the only real thing is our brain receiving certain impressions. But they will never persuade the mass of humanity to regard the world as anything but a very real thing. Try to make a man who has just hit his head against a wall, or fallen downstairs, believe that he has not really been struck, and that it is only a delusion of his senses, and he will either feel inclined to strike the persuasive person who makes the remark or to reply that it is quite as real to him whichever way it is; and he knows, too, that the doctor's charge will really affect his pocket in the way of making his purse lighter. So the reality of matter is firmly fixed in the mind of mankind; and not even a surgical operation can make him believe that it is all a joke or a sport of nature.

Having implanted in our minds the chief properties of matter, we shall then proceed to exemplify the various studies of nature that can be satisfactorily pursued in the open air without expensive apparatus. The variety of charming creatures that can be found on our field excursions is much greater than is ordinarily realised. Stones, mud, slime, pond water, insects, nests, flowers, leaves, fungi, seaweeds, all furnish subjects for many a day's examination. Air and water in their different conditions afford material for profoundly interesting observations which any one may make. Gradually we acquire a perception of different forces of nature which may be separately understood and followed out through a variety of purposes. Attraction and cohesion will lead us through very interesting phenomena. We shall gradually acquire a notion of what is meant by a centre of gravity, and how from this follows the principle of the balance,—a principle which in all its variations is well worth studying; for the balance is used in an

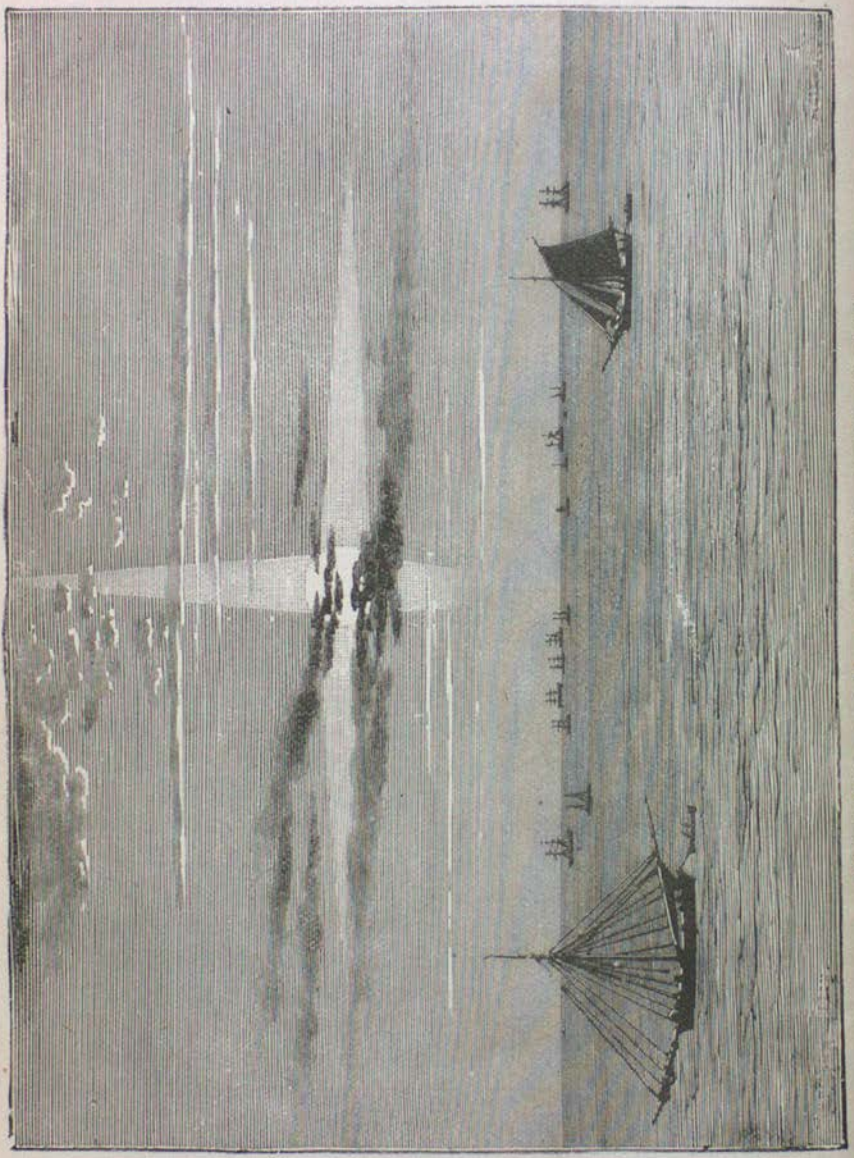
infinite number of operations in life, and many are the occasions on which it would be extremely useful to us to be able to say positively whether a balance is correct or not. The question of equilibrium, too, is of a most practical nature; for we continually have to arrange our own loads so as to balance, or to place things on tables or shelves so that they shall not fall down. The knowledge of how to tell the relative weight of liquids is of great importance to us in estimating the purity of milk, oils, etc. The pressure of the air is of interest to every one, though it is so equally adjusted that we never feel it except when strong winds attack us ; but it produces many of the variations of the weather, and none of us can be really indifferent to it. The barometer, the air-pump, the diving-bell, the pendulum, ballooning, the syphon, the Bramah press, capillarity, and buoyancy,—these are a few of the many subjects upon which we shall touch, each of which is calculated to reward the patient student, to enlarge the capacity of his mind, to give him new powers of appreciation of nature, and to make him in manifold ways a wiser and more capable being.

CHAPTER I.—THE STUDY OF NATURE.

THE BOOK OF NATURE—THE SENSES—NATURAL HISTORY—NATURAL PHILOSOPHY—MATTER—OBJECTS—PROPERTIES OF MATTER.

BERNARD PALISSY used to say that he wished "no other book than the earth and the sky," and that "it was given to all to read this wonderful book."

It is indeed by the study of the material world that discoveries are accomplished. Let an attentive observer watch a ray of light passing from the air into water, and he will see it deviate from the straight line by refraction; let him seek the origin of a sound, and he will discover that it results from a shock or a vibration. This is physical science in its infancy. It is said that Newton was led to discover the laws of universal gravitation by beholding an apple fall to the ground, and that Montgolfier first dreamt of air-balloons while watching fogs floating in the atmosphere. The idea of the inner chamber of the eye may, in like manner, be developed in the mind of any observer, who, seated beneath the shade of a tree, looks fixedly at the round form of the sun through the openings in the leaves.



Luminous Cross seen at Havre, May 7th, 1877 Sketched from Nature.

Every one, of course, may not possess the ambition to make such discoveries, but there is no one who cannot compel himself to learn to enjoy the pleasure that can be derived from the observation of Nature.

It must not be imagined that in order to cultivate science it is absolutely necessary to have laboratories and scientific work-rooms. The book of which Palissy spoke is ever present; its pages are always open, wherever we turn our eyes or direct our steps. So we may hope to introduce all our friends to a pleasant and lasting acquaintance with Dame Nature.

"But what *is* Nature?" We are fond of admiring Nature, and the effects of certain causes in the world, and we want to know why things are so. Very well—so you shall; and as to the question, "What is Nature?" we will endeavour to answer you at once.

Nature is the united totality of all that the various Senses can perceive. In fact, all that cannot be made by man is termed "Nature"; *i.e.*, God's creation.

From the earliest ages man has sought to read the open leaves of the Book of Nature, and even now, with all our attainments, we cannot grasp all, or nearly all. One discovery only leads up to another. Cause and Effect are followed up step by step till we lose ourselves in the search. Every effect must have a cause. One thing depends upon another in the world, and it does not need Divine revelation to tell us that. Nothing happens by "mere chance." "Chance!" said a Professor to us at the University, "Chance!—Remember, there is no such thing in the world as chance."

Between our minds or consciousness and Nature are our Senses. We feel, we see, we hear, we taste, we smell, —so it is only through the Senses that we can come to any knowledge of the outer world. These attributes, or Senses, act directly upon a certain "primary faculty"

called Consciousness, and thus we are enabled to understand what is going on around us. The more this great existing faculty is educated and trained, the more useful it will become. So if we accustom our minds to observation of Nature, we shall find out certain causes and effects, and discover Objects. Now an Object is a thing perceptible both to feeling and sight, and an Object occupies space. Therefore there are objects Artificial as well as Natural. The former are created by man from one or more Natural products. Natural Objects are those such as trees, rocks, plants, and animals. We may also class the heavenly bodies, etc., as Objects, though we cannot touch them, but we can feel their effects, and see them. The PHENOMENA of Nature include those results which are perceptible by only one sense, as thunder; light and sound may also be classed as Phenomena.

Take a familiar instance. A stone is a Natural Object. We take it up, open our fingers, and it falls. The *motion* of that object is a Phenomenon. We know it falls, because we see it fall, and it possesses what we term *weight;* but we cannot tell *why* it possesses weight.

[Professor Huxley says: "Stones do not fall to the ground in consequence of a law of nature," for a law is not a cause. "A law of nature merely tells us what we may expect natural objects will do under certain circumstances."]

A cause of a Phenomenon being independent of human will is called a *Force*, and the stones fall by the force of *Gravitation*, or that natural law which compels every material object to approach every other material object.

A single Force may produce a great number of Phenomena.

Nature being revealed to us by Objects, and by means of Phenomena, we have got already two Branches of Science extending from such Roots; viz., NATURAL

HISTORY, the Science of Objects; and NATURAL PHILOSOPHY, the Science of Phenomena.

Both of these branches have been subdivided thus:

Natural History	Zoology, referring to Animals; Botany, referring to Plants	Biology.
	Mineralogy; Geology	referring to Minerals, etc.
Natural Philosophy	Physics.	Phenomena without essential change of the Objects.
	Chemistry.	Phenomena with change of the Objects.
	Physiology.	Phenomena of animated Objects.

These two great divisions comprehend, in their extended senses, all that is known respecting the material world.

We have spoken of Objects. Objects occupy *Space*. What is Space?—Space is magnitude which can be conceived as extending in three directions—*Length*, *Breadth*, and *Depth*. MATTER occupies portions of Space, which is infinite. Matter, when finite, is termed a body or object. The general properties of Matter are *Magnitude*, *Form*, *Impenetrability*, *Inertia*, *Divisibility*, *Porosity*, *Elasticity*, *Compressibility*, *Expansibility*.

Matter is present in Nature in three conditions. We find it as a SOLID, a LIQUID, and a GAS. We shall explain the various properties of Solids, Liquids, and Gases in their proper places (in Physics). To test the actual existence of Matter in one or other of these forms our Senses help us. We can touch a Solid, or taste it and see it. But touch is the test. We have said that Matter possesses certain properties. We will examine these briefly. The two which belong to all material bodies are Impenetrability and Magnitude. You cannot, *strictly speaking*, penetrate Matter. You can find the form of an

object by touch or sight, but you cannot penetrate it. You will think you can drive a nail or a screw into a board, but you cannot; you only *displace* the fibres of the wood by the screw. Take water as a very common instance. Water is Matter, for it occupies a certain space. Water is *impenetrable*, for if you put your hand or foot into a basin full of it, it will overflow, thus proving that you displace, and do not penetrate it. It is almost impossible to compress water.

Divisibility is another quality of Matter; and when we attempt to show how far Matter can be divided, the brain refuses to grasp the infinity. A pin's head is a small object, but it is gigantic compared to some animals, of which millions would occupy a space no larger than the head of a pin. These tiny animals must contain organs and veins, etc., and those veins are full of blood globules. Professor Tyndall informs us that a drop of blood contains three millions of red globules. So these infinitesimally small animals must have millions of globules in their blood also. Thus we see to what an extent, far beyond our Senses' power to grasp, Matter can be divided.

But there is something even more astonishing than this. It is stated that there are more germs in the milt of a single codfish than there are men in the world; and that *one grain of sand is larger than four millions of these germs!* each of which must be possessed of life germs of an equal amount, which would grow up as it grew to maturity. This carries us back again, and

"Imagination's utmost stretch
In wonder dies away."

Or take other interesting facts. One hundred threads of the silkworm must be placed side by side to make up the thickness of a line (—) about $\frac{1}{25}$th of an inch; and metals can be drawn out to such exceeding fineness that twelve hundred of the fine wires will occupy only the

space of one hundred silkworms' threads, or one *millimetre.*

Porosity is another attribute of Matter, for in all Matter there are pores, or spaces, between the particles. Sometimes such openings are plainly visible; in very "solid" bodies, they are, to a great extent, indistinguishable. But we know that the spaces exist, because we can *compress* the particles together.

Inertia is also a general property of Matter, and the meaning of the term is "inactivity," or passiveness—a want of power in an object to move, or when moving, to stop of itself. It will come to rest apparently by itself, but the resistance of the air and the friction of the ground, or the attraction of the earth, will really occasion the stoppage of the object. We will speak more fully of Inertia presently. Elasticity and Expansibility are evident in fluids and gases.

We have thus introduced our readers to some of the most evident facts connected with Matter. The various Forces and Phenomena of attraction will be fully considered farther on; at present we are about to show our readers how they may first profitably study Science in the open air for themselves, and we will give them our experience of the Book of Nature.



CHAPTER II.—SCIENCE IN THE OPEN AIR.

APHIDES—EVAPORATION BY LEAVES—AN AQUARIUM—THE CATALEPTIC FOWL—NEEDLE POINTS AND THORNS—MICROSCOPIC AQUARIUM—CAPE GRISNEZ—CRYSTALS—ICE ON THE GAS LAMPS.

SOME years ago we were staying in Normandy, not far from the town of C——, enjoying, in the midst of most cordial hospitality, the peacefulness of country life; and my kind hosts, with me, took great pleasure in having what we called "a course of science in the open air." The recollections of that time are some of the pleasantest in the whole course of my life, because all our leisure was intelligently occupied. Each of us set himself to provide the subject of some curious observation or instructive experiment; one made a collection of insects, another studied botany. In the daytime we might have been seen examining, under a magnifying glass, the branch of a rose-tree, from which the ants were endeavouring to extract the aphides.* At night we admired through the telescope the stars and planets that were visible; or if the sky was not clear, we examined under a strong magnifier grains of pollen from flowers, or the *infusoria* in a drop of stagnant water. Frequently some very insignificant object became the occasion for

* It is well known that ants, by touching the skin of aphides, extract therefrom a secretion of viscous matter, which nourishes them. They will frequently carry off the aphides to their habitations, and keep them here; thus one may say they *keep a cow in their stable.*

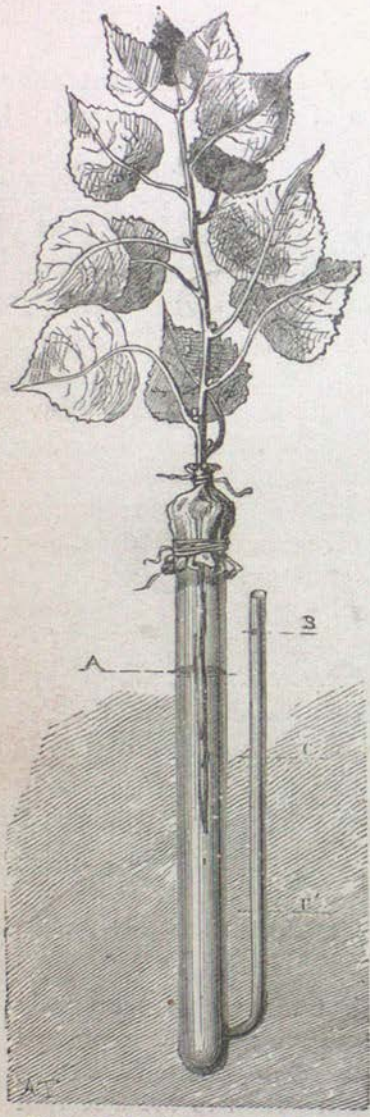
some scientific discussion, which terminated with an experimental verification.

I recollect that one day one of us remarked that after a week of dry weather a stream of water had nearly dried



Ants engaged in extracting aphides from a rose-tree (highly magnified).

up, although sheltered by thick trees, which necessarily impeded the calorific action of the sun ; and he expressed surprise at the rapid evaporation. An agriculturist among the company, however, drew his attention to the fact that the roots of the trees were buried in the course of the



Experiment showing evaporation of water by leaves.

stream, and that, far from preventing the evaporation of the water, the leaves had contributed to accelerate it. As the first speaker was not convinced, the agriculturist, on our return to the house, prepared an experiment represented in margin. He placed the branch of a tree covered with foliage in a U-shaped tube, the two branches of unequal diameter, and filled with water. He placed the vegetable stem in the water, and secured it to the tube by means of a cork covered with a piece of india-rubber, and tied tightly to make it hermetically closed.

At the commencement of the experiment the water was level with A in the larger branch of the tube, and level with B in the smaller, rising to a slightly higher point in the more slender of the two by capillarity. The evaporation of the water caused by the leaves was so active that in a very short time we beheld the water sink to the points C and C.

Thus did the excellent method of seeking the cause of phenomena by experiments often lead us to interesting results. We had among us many children and young people who had reached the age of ardent curiosity. We took pleasure in pointing out to them the means of studying natural science; and we were not long before feeling convinced that our lessons out in the fields had much greater success than those given between the four walls of a class-room. Insects were collected, and preserved by being carefully placed in a small bottle, into which was let fall a drop of sulphuret of carbon;* the insect was immediately asphyxiated, and we thus avoided the cruelty of passing a pin through a living body. Having chased butterflies and insects, we next desired to study the aquatic creatures which swarmed in the pools of the neighbourhood. For this purpose I constructed a fishing-net fitted to an iron ring, and firmly secured to a wooden handle. When this was plunged under the water and drawn quickly out again, it came back full of slime. In the midst of this muddy substance one generally succeeded in finding the hydrophilus, tadpoles, coleoptera, many curious kinds of caddis-worms, tritons, and sometimes frogs, completely astounded by the rapidity of their capture. All these creatures were transported in a bottle to the house, and I then constructed, at small expense, a glass aquarium, by means of the bell of a melon-glass turned upside down,

* The preservation of insects, and their preparation for collections, necessitates some precaution. Entomologists are in the habit of spreading them out on a small board, and arranging the legs and *antennæ* by means of large pins. The wings should be dried by placing them on strips of paper, which preserves them. These precautions are indispensable if it is wished that the insects in a collection should retain their distinctive characters. Worms and caterpillars can be raised in pots filled with earth, if carefully covered over with muslin or wire gauze with very fine meshes. The process of hatching may give rise to many interesting observations.

thus forming a transparent receptacle of considerable size. Four wooden stakes were then fixed in the ground, and a plank with a circular hole nailed on the top, in which the



Aquarium formed by means of a melon-glass.

glass bell was placed. I next scattered some large pebbles and shells at the bottom of the vase to form a stony bed, poured in some water, placed a few reeds and water plants among the pebbles, and then threw a handful of water

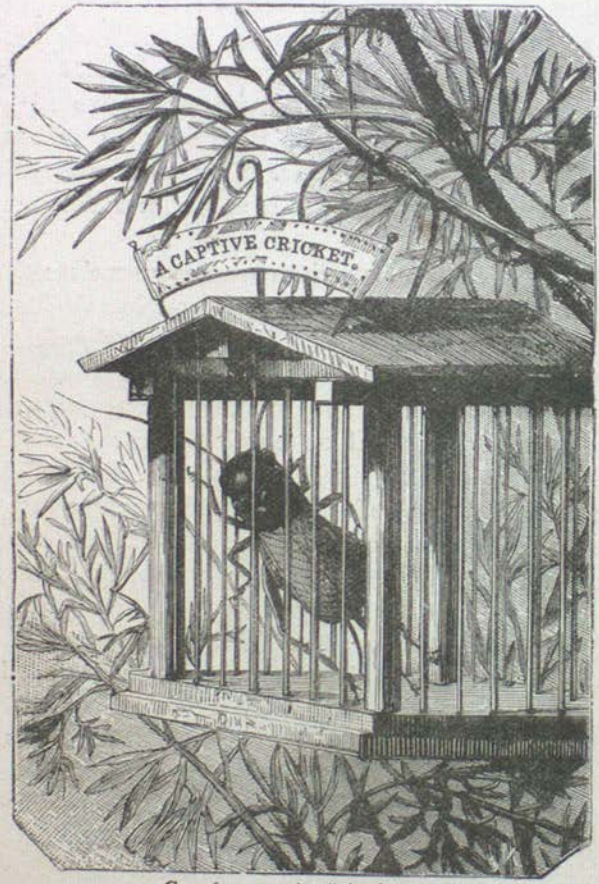
lentils on the surface; thus a comfortable home was contrived for all the captured animals.* The aquarium, when placed under the shade of a fine tree in a rustic spot abounding with field flowers, became a favourite rendezvous, and we often took pleasure in watching the antics of the little inmates. Sometimes we beheld very sanguinary scenes; the voracious hydrophilus would seize a poor defenceless tadpole, and rend him in pieces for a meal without any compunction. The more robust tritons defended themselves better, but sometimes they also succumbed in the struggle.

The success of the aquarium was so complete that one of us resolved to continue this museum in miniature, and one day provided himself with an *insects' palace*, which nearly made us forget the tadpoles and tritons. It was a charming little cage, having the form of a house, covered with a roof; wires placed at equal distances forming the sides. In it was a large cricket beside a leaf of lettuce, which served as his food. The little creature moved up and down his prison, which was suspended from the branch of a tree, and when one approached him very closely gave vent to his lively chirps.

The menagerie was soon further augmented by a hitherto unthought-of object; namely, a frogs' ladder. It was made with much skill. A large bottle served for the base of the structure. The ladder which was fixed in it was composed of the twigs of very small branches, recently cut from a tree, and undivested of their bark, which gave to the little edifice a more picturesque and rustic appearance. The pieces of wood, cleverly fixed into two posts, conducted the green frogs (tree-frogs) on to a platform, whence they ascended the steps of a

* It frequently happens that in a small aquarium, constructed after this fashion, the animals escape. This is avoided by covering the vase with a net.

genuine ladder. There they could disport themselves at pleasure, or climb up further to a branch of birch-tree placed upright in the centre of the bottle. A net with



Cage for preserving living insects.

fine meshes prevented the little animals from escaping. We gave the tree-frogs flies for their food, and sometimes they caught them with remarkable dexterity. I have often seen a frog when at liberty watching a fly, on which

it pounces as a cat does on a bird. The observations that we made on the animals of our menagerie led us to undertake others of a very different nature; I recollect



Small aquarium, with frogs' ladder.

particularly a case of catalepsy produced in a cock. I will describe this remarkable experiment, certainly one of the most curious we ever performed.

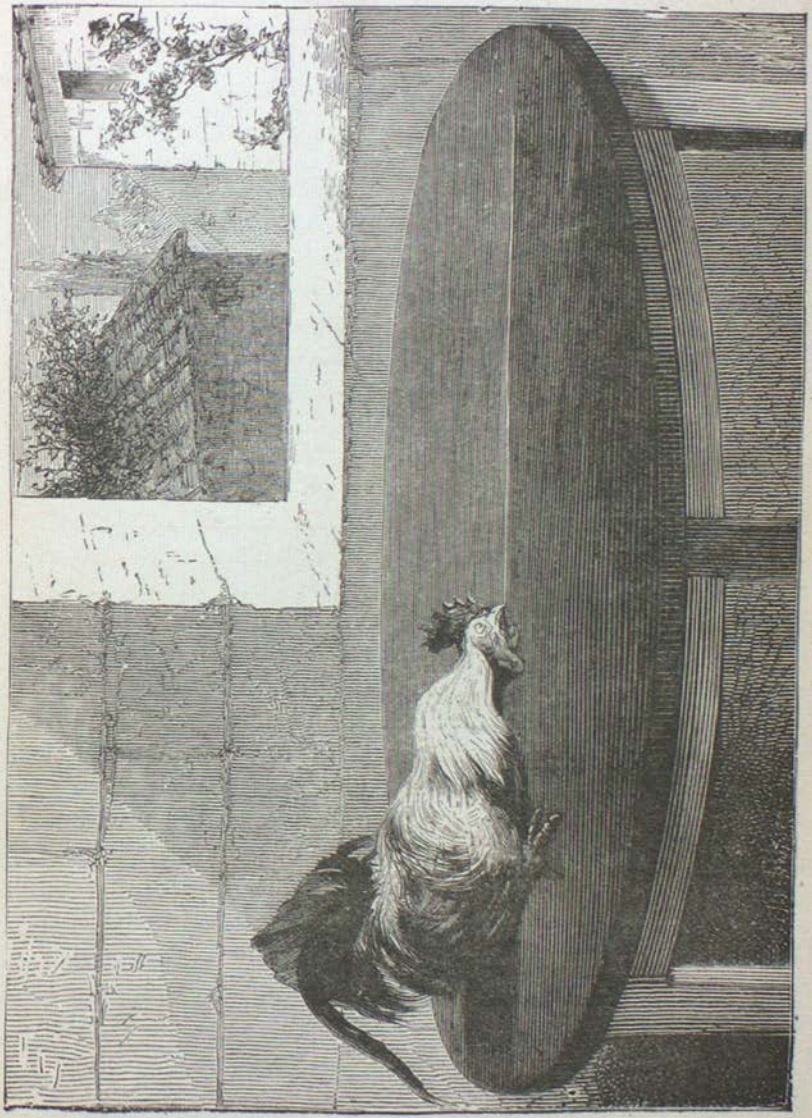
We place a cock on a table of dark colour, rest its

beak on the surface, where it is firmly held, and with a piece of chalk slowly draw a white line in continuation from the beak, as shown in our engraving. If the crest is thick, it is necessary to draw it back, so that the animal



Frog lying in wait for a fly.

may follow with his eyes the tracing of the line. When the line has reached a length of two feet the cock has become cataleptic. He is absolutely motionless, his eyes are fixed, and he will remain from thirty to sixty seconds in the same posture in which he had at first only been held by force. His head remains resting on the table in

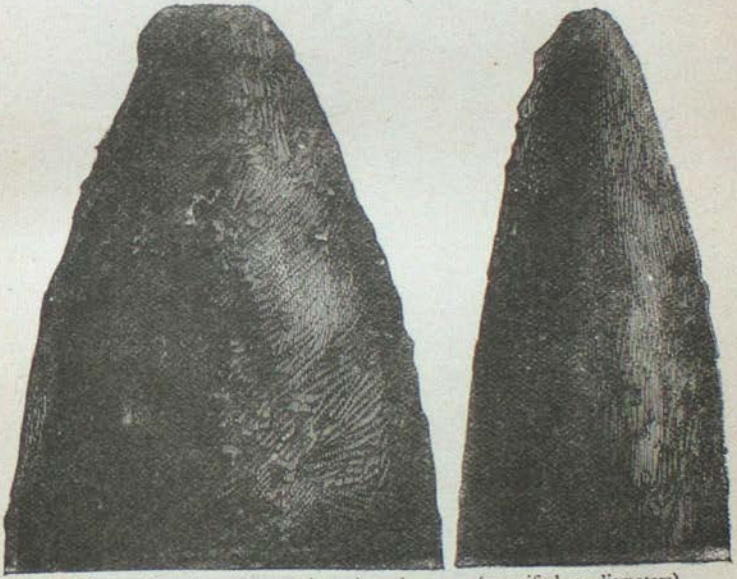


Experiment of the cataleptic cock.

the position shown. This experiment, which we have successfully performed on different animals, can also be accomplished by drawing a straight line with a piece of chalk on a slate. M. Azam declares that the same result is also produced by drawing a black line on a table of white wood. According to M. Balbiani, German students had formerly a great predilection for this experiment, which they always performed with marked success. Hens do not, when operated on, fall into a cataleptic condition so easily as cocks; but they may often be rendered motionless by holding their heads fixed in the same position for several minutes. The facts we have just cited come properly under the little studied phenomena, designated by M. Braid in 1843 by the title of *Hypnotism.* MM. Littré and Ch. Robin have given a description of the hypnotic condition in their *Dictionnaire de Médecine.*

If any shining object, such as a lancet, or a disc of silver-paper gummed to a plate, is placed at about the distance of a foot from the eyes of a person, slightly above the head, and the patient regards this object fixedly, and without interruption for twenty or thirty minutes, he will become gradually motionless, and in a great number of cases will fall into a condition of torpor and genuine sleep. Dr. Braid affirms that under such circumstances he has been able to perform surgical operations without the patient having any consciousness of pain. Later also, M. Azam has proved the complete insensibility to pricking on the part of individuals whom he has rendered cataleptic by the fixing of a brilliant object. The experiment of the cataleptic cock was first described under the name of *Experimentum Mirabile*, by P. Kircher, in his *Ars Magna*, published at Rome in 1646. It evidently belongs to the class of experiments which were performed at the Salpêtrière asylum at Paris, by M. Charcot, on patients suffering from special disorders. It must now be evident

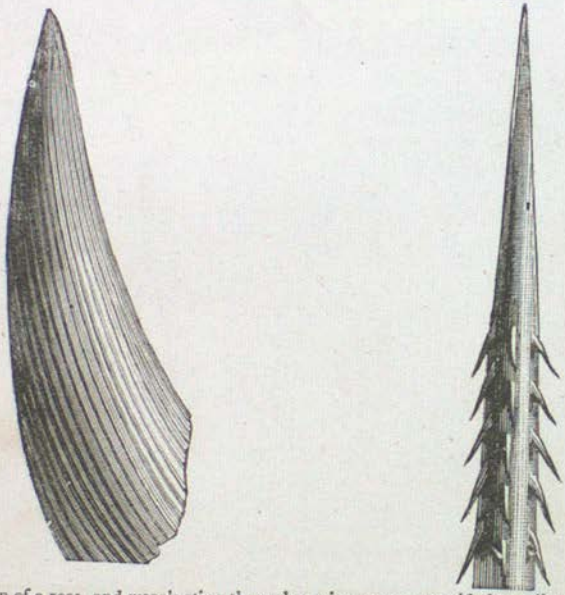
to our readers that our scientific occupations were sufficiently varied, and that we easily found around us many objects of study. When the weather was wet and cloudy we remained indoors, and devoted ourselves to microscopical examinations. Everything that came under our hands, insects, vegetables, etc., were worthy of observation. One day, while engaged over a microscopical preparation,



Ordinary pin and needle, seen through a microscope (magnified 500 diameters).

I was making use of one of those steel points generally employed in such purposes, when happening to pass it accidentally beneath the microscope, I was astonished to see how rough and uneven it appeared when highly magnified. The idea then occurred to me to have recourse to something still more pointed, and I was thus led to make comparisons between the different objects represented. It will here be seen how very coarse is the product of our industry when compared with the product of Nature.

No. 1 represents the point of a pin that has already been used, magnified 500 diameters. The point is evidently slightly blunted and flattened. The malleable metal has yielded a little under the pressure necessary to make it pass through a material. No. 2 is a little more pointed; it is a needle. This, too, will be seen to be defective when regarded by the aid of the microscope. On the



Thorn of a rose, and wasp's sting through a microscope (magnified 500 diameters).

other hand, what fineness and delicacy do the rose thorn and wasp's sting present when examined under the same magnifier! See the two points in illustration.

An examination of this exact drawing has led me to make a calculation which leads to rather curious results: at a half millimetre from the point, the diameters of the four objects represented are in thousandths of a millimetre respectively, 3·4; 2·2; 1·1; 0·38. The corresponding sections in millionths of a square millimetre are:

907·92 ; 380·13 ; 95·03 ; 11·34 ; or, in round numbers, 908 ; 380 ; 95 ; 11.

If one bears in mind, which is much below the truth, that the pressure exercised on the point must be proportional to the section, and admitting that a pressure of 11 centigrams suffices to thrust in the sting of a wasp half a millimetre, it will require more than 9 grams of pressure to thrust in a needle to the same extent. In fact, this latter figure is much too small, for we have not taken into account the advantage resulting from the elongated shape of the rose thorn, which renders it more favourable for penetration than a needle through a drop of tallow.

It would be easy to extend observations of this kind to a number of other objects, and the remarks I have just made on natural and artificial points will apply incontestably to textures for example. There is no doubt that the thread of a spider's web would far surpass the thread of the finest lace, and that art will always find itself completely distanced by nature.

We amused ourselves frequently by examining the *infusoria* which are so easily procured by taking from some stagnant water the mucilage adhering to the vegetation on the banks, or attached to the lower part of water lentils. In this way we easily captured *infusoria*, which, when placed under a strong magnifier, presented the most remarkable spectacle that one can imagine. They are animalcules, having the form of transparent tulips attached to a long stem. They form bunches which expand and lengthen ; then, suddenly, they are seen to contract with such considerable rapidity that the eye can scarcely follow the movement, and all the stems and flower-bells are folded up into the form of a ball. Then, in another moment, the stems lengthen, and the tulip-bells open once more. One can easily encourage

the production of *infusoria* by constructing a small microscopic aquarium, in which one arranges the centre in a manner favourable to the development of the lowest



Arrangement of a microscopic aquarium for examining *infusoria*.

organisms. It suffices to put a few leaves (a piece of parsley answers the purpose perfectly)* in a small vase

* The infusion of parsley has the advantage of not sensibly obscuring the water.

containing water, over which a glass cover is placed, and it is then exposed to the rays of the sun. In two or three days' time, a drop of this water seen under the microscope will exhibit *infusoria*. After a certain time, too, the different species will begin to show themselves. Microscopical observations can be made on a number of different objects. Expose to the air some flour moistened by water, and before long a mouldiness will form on it; it is the *penicillium glaucum*, and when examined under a magnifier of 200 to 300 diameters, cells are distinguishable, branching out from an organism remarkable for its simplicity. We often amused ourselves by examining, almost at hazard, everything that came within our reach, and sometimes we were led to make very instructive investigations. When the sky was clear, and the weather favourable to walking, we encouraged our young people to run about in the fields and chase butterflies. The capture of butterflies is accomplished, as every one knows, by means of a gauze net, with which we provided the children, and the operation of chasing afforded them some very salutary exercise. It sometimes happens that butterflies abound in such numbers that it is comparatively easy to capture them. During the month of June 1879, a large part of Western Europe was thronged with swarms of *Vanessa algina* butterflies, in such numbers that their appearance was regarded as an important event, and attracted the lively attention of all entomologists. This passage of butterflies provided the occasion for many interesting studies on the part of naturalists.

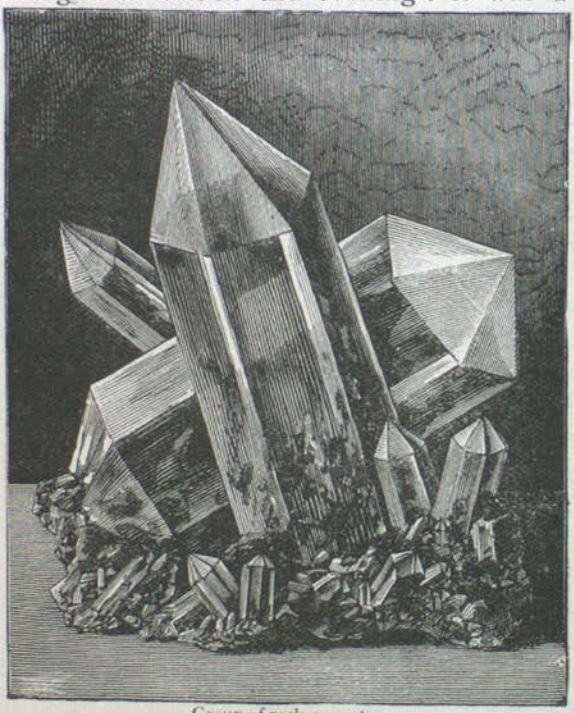
We cannot point out too strongly to our readers that the essential condition for the student of natural science, is the possession of that sacred fire which imparts the energy and perseverance necessary for acquiring and enlarging collections. It is also necessary that the investigator should furnish himself with certain indispensable tools.



Flight of butterflies seen near Berne, June 15th, 1879.

For collecting plants the botanist should be armed with a good hoe set in a thoroughly strong handle, a trowel, of which there is a variety of shapes, and a knife with a sharp blade. A botanical case must also be included, for carrying the plants. The geologist, or mineralogist, needs no more elaborate instruments ; a hammer, a chisel, and a pickaxe with a sharp point for breaking the rocks, and a bag for carrying the specimens, will complete his outfit. We amused ourselves by having these instruments made by the blacksmith, sometimes even by manufacturing them ourselves ; they were simple, but solid, and admirably adapted to the requirements of research. Often we directed our walks to the seashore, where we liked to collect shells on the sandy beach, or fossils among the cliffs and rocks. I recollect, in a walk I had taken some years previously along the foot of the cliffs of Cape Blanc-Nez, near Calais, having found an impression of an ammonite of remarkable size, which has often excited the admiration of amateurs ; this ammonite measured no less than twelve inches in diameter. The rocks of Cape Grisnez, not far from Boulogne, also afford the geologian the opportunity of a number of curious investigations. In the Ardennes and the Alps I have frequently procured some fine mineral specimens ; in the first locality crystallized pyrites, in the second fine fragments of rock crystal. I did not fail to recount these successful expeditions to the young people who accompanied me, and their ardour was thereby inflamed by the hope that they also should find something valuable. It often happened when the sun was powerful, and the air extremely calm, that my young companions and I remarked some very beautiful effects of mirage on the beach, due to the heating of the lower *strata* of the atmosphere. The trees and houses appeared to be raised above a sheet of silver, in which their reflections were visible as in a sheet of tranquil

water. It can hardly be believed how frequently the atmosphere affords interesting spectacles which pass unperceived before the eyes of those who know not how to observe. I recollect having once beheld at Jersey a magnificent phenomenon of this nature, on the 24th June, 1877, at eight o'clock in the evening: it was a column



Group of rock crystal.

of light which rose above the sinking sun like a sheaf of fire. I was walking on the St. Helier pier, where there were also many promenaders, but there were not more than two or three who regarded with me this mighty spectacle. Columns and crosses of light are much more frequent than is commonly supposed, but they often pass unperceived before indifferent spectators. We will

describe an example of this phenomenon observed at Havre on the 7th May, 1877. The sun formed the centre of the cross, which was of a yellow golden colour. This cross had four branches. The upper branch was much more brilliant than the others; its height was about 15°. The lower branch was smaller, as seen in the sketch on page 2, taken from nature by Monsieur Albert Tissandier. The two horizontal branches were at times scarcely visible, and merged in a streak of reddish-yellow colour, which covered a large part of the horizon. A mass of cloud, which the setting sun tinged with a deep violet colour, formed the foreground of the picture. The atmosphere over the sea was very foggy. The phenomenon did not last more than a quarter of an hour, but the conclusion of the spectacle was signalized by an interesting circumstance. The two horizontal branches, and the lower branch of the luminous cross, completely disappeared, whilst the upper branch remained alone for some minutes longer. It had now the appearance of a *vertical column* rising from the sun, like that which Cassini studied on the 21st May, 1672, and that which M. Renon* and M. A. Guillemin observed on the 12th July, 1876.† Vertical columns, which, it is well known, are extremely rare phenomena, may therefore indicate the existence of a luminous cross, which certain atmospheric conditions have rendered but partially visible.

How often one sees along the road little whirlwinds of dust raised by the wind accomplishing a rotatory movement, thus producing the imitation of a waterspout! How often halos encompass with a circle of fire the sun or

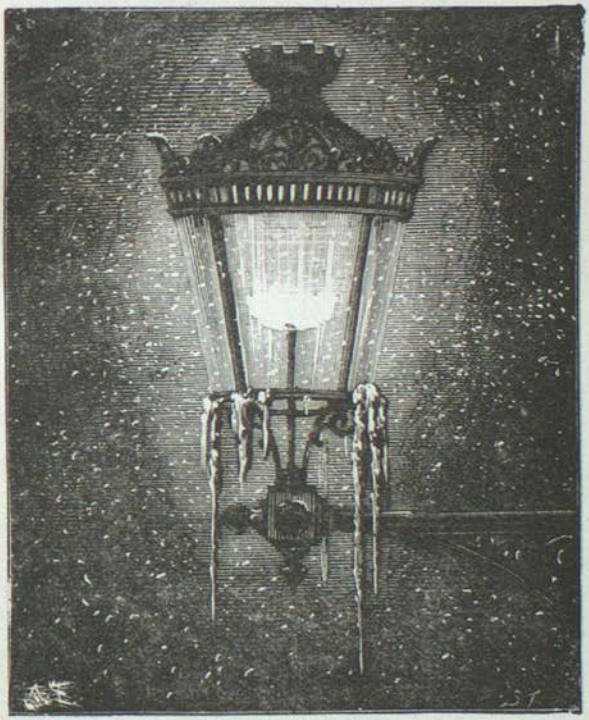
* Detailed accounts in Vol. lxxxiii, pp. 243 and 292 of "*La Nature*."

† See "*La Nature*," 4th year, 1876, 2nd half-year, p. 167. M. A. Guillemin mentions, in connection with the phenomenon of July 12th, 1876, the presence of light masses of cloud of a greyish-blue colour, similar to those perceived in the phenomena just described.

the stars! How often we see the rainbow develop its iridescent beauties in the midst of a body of air traversed by bright raindrops! And there is not one of these great natural manifestations which may not give rise to instructive observations, and become the object of study and research. Thus, in walks and travels alike, the study of Science may always be exercised; and this method of study and instruction in the open air contributes both to health of body and of mind. As we consider the spectacles which Nature spreads before us,—from the insect crawling on the blade of grass, to the celestial bodies moving in the dome of the heavens,—we feel a vivifying and salutary influence awaken in the mind. The habit of observation, too, may be everywhere exercised—even in towns, where Nature still asserts herself; as, for example, in displays of meteorological phenomena. We will give an example of such.

The extraordinary abundance of snow which fell in Paris for more than ten consecutive hours, commencing on the afternoon of Wednesday, January 22nd, 1880, will always be looked upon as memorable among the meteorological events of the city of Paris. It was stated that in the centre of Paris, the thickness of the snow that had fallen at different times exceeded fourteen inches. The snow had been preceded by a fall of small transparent icicles, of rather more than a millimetre in diameter, some having crystalline facets. They formed on the surface of the ground a very slippery glazed frost. On the evening of the 22nd January, flakes of snow began to hover in the atmosphere like voluminous masses of wool. The greater part of the gas-lamps were ornamented by frozen stalactites, which continually attracted the attention of passers-by. The formation of these stalactites, of which we give a specimen, is easy of explanation. The snow falling on the glass of the lamp became heated by the flame of gas,

melted, and trickled down, freezing anew into the shape of a stalactite below the lamp, at a temperature of 0° centigrade. Not only can meteorology be studied in towns, but certain other branches of natural science—entomology, for example. We will quote what a young

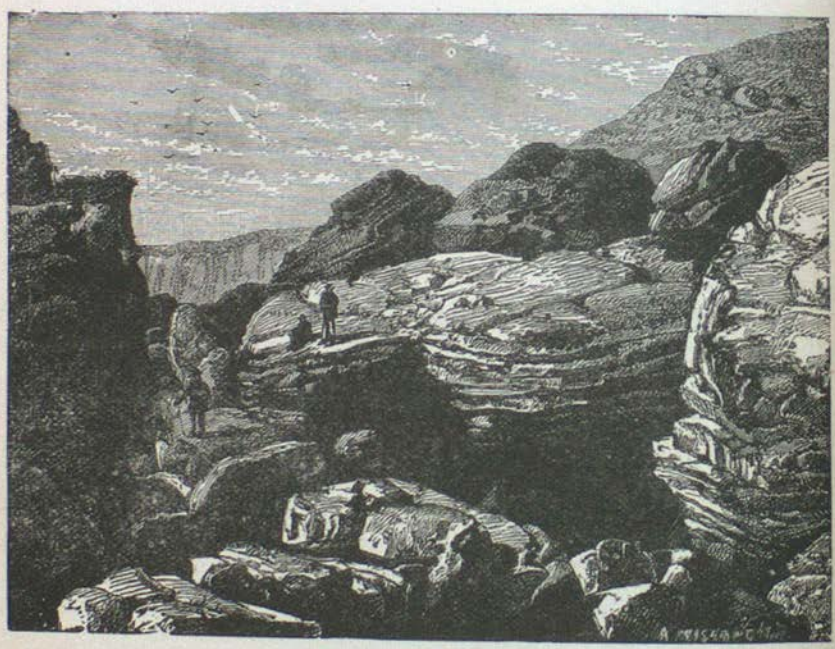


Icicles on gas lamp.

student in science, M. A. Dubois, says on this very subject: "Coleoptera," he declares, "are to be met with everywhere, and I think it may be useful to notice this fact, supporting it by examples. I desire to prove that there are in the midst of our large towns spots that remain unexplored, where some fine captures are to be

made. Let us visit, at certain times, the approaches to the quays, even at low tide, and we shall be surprised to find there species which we have searched for far and near." This opinion is confirmed by the enumeration of several interesting captures.

Was not the great Bacon right when he said, "For the keen observer, nothing in Nature is mute"?



The cliffs of Cape Grisnez.

CHAPTER III.—SIMPLE PHYSICS.

THE MEANING OF PHYSICS — FORCES OF NATURE — GRAVITY — COHESION — CHEMICAL ATTRACTION — CENTRE OF GRAVITY—EXPERIMENTS—AUTOMATON TUMBLERS.

HAVING now introduced our readers to Science which they can find for themselves in the open air, and the pursuit of which will both instruct and amuse, we will proceed to investigate the Branch of Science called PHYSICS.

PHYSICS may be briefly described as the Branch of Natural Science which treats of such phenomena as are unaccompanied by any important changes in the objects wherein such phenomena are observed.

For instance, the sounding of a bell or the falling of a stone are physical phenomena, for the objects which cause the sound, or the fall, undergo no change. Heat is set free when coal burns. This disengagement of heat is a physical phenomenon ; but the change during combustion which coal undergoes is a *chemical* phenomenon. So the objects may be the same, but the circumstances in which they are placed, and the forces which act upon them, may change their appearance or position.

This brings us at once to the *Forces of Nature*, which are three in number ; viz., Gravity, Cohesion, and Affinity, or Chemical Attraction. The phenomena connected with the last-named forms the Science of *Chemistry*. We give these three Forces these names. But first we must see

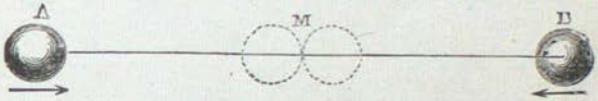
what is Force, for this is very important. Force is a CAUSE—the cause of Motion or of Rest. This may appear paradoxical, but a little reflection will prove it. It requires force to set any object in motion, and this body would never stop unless some other force or forces prevented its movement beyond a certain point. Force is therefore the cause of a change of " state " in matter.

We have said there are three forces in nature. The first is Gravity, or the attraction of particles at a distance from each other. We may say that Gravity, or Gravitation, is the mutual attraction between different portions of matter acting at all distances,—the force of attraction being, of course, in proportion to the mass of the bodies respectively. The greatest body is the Earth, so far as our purposes are concerned. So the attraction of the Earth is *Gravity*, or what we call *Weight.*

We can easily prove this. We know if we jump from a chair we shall come to the floor; and if there were nothing between us and the actual ground sufficient to sustain the force of the attracting power of the earth, we should fall to the earth's surface. In a teacup the spoon will attract air bubbles, and large air bubbles will attract small ones, till we find a small mass of bubbles formed in the centre of the cup of tea. Divide this bubble, and the component parts will rush to the sides of the cup. This form of attraction is illustrated by the accompanying diagrams.

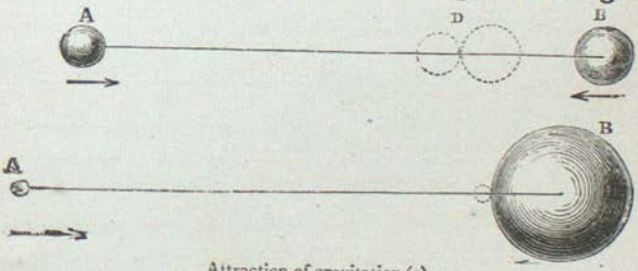
Suppose two balls of equal magnitude, A and B. These being of equal magnitude, attract each other with equal force, and will meet, if not opposed, at a point (M) halfway between the two. But they do not meet, because the attraction of the earth is greater than the attraction they relatively and collectively exercise towards each other. But if the size of the balls be different, the attraction of the greater will be more evident, as shown opposite

where the points of meeting are indicated respectively. These experiments will illustrate the phenomena of *falling bodies.* Gravity is the cause of this, because every object on the surface of the earth is very much smaller than the earth itself, and therefore all bodies *fall* towards the centre of the earth. A certain time is



Attraction of gravitation (1).

thus occupied, and we can find the *velocity* or rapidity of a falling body very easily. On the earth a body, if let fall, will pass through a space sixteen feet in the first second; and as the attraction of the earth still continues and is exercised upon a body already in rapid motion, this rate of progress must be proportionately increased. Just as when steam is kept up in an engine running down



Attraction of gravitation (2).

hill, the velocity of the train will rapidly increase as it descends the gradient.

A body falling, then, descends sixteen feet in the first second, and for every succeeding second it assumes a greater velocity. The distance the body travels has been calculated, and the space it passes through has been found to *increase in proportion to the square of the time it takes to fall.* For instance, suppose you drop a stone from the top of a cliff to the beach, and it occupies two seconds in

falling, if you multiply 2 × 2, and the result by sixteen, you will find how high the cliff is: in this (supposed) case it is (omitting decimals) sixty-four feet high. The depth of a well can also be ascertained in the same way, leaving out the effect of air resistance.

But if we go up into the air, the force of gravity will be diminished. The attraction will be less, because we are more distant from the centre of the earth. This decrease is scarcely, if at all, perceptible, even on very high mountains, because their size is not great in comparison with the mass of the earth's surface. The rule for this is *that gravity decreases in proportion to the square of the distance.* So that if at a certain distance from the earth's surface the force of attraction be 1, if the distance be *doubled* the attraction will be only *one quarter* as much as before—not one-half.

Gravity has exactly the same influence upon *all* bodies, and the force of the attraction is in proportion to the mass. All bodies of equal mass will fall in the same time in a given distance. Two coins (or a coin and a feather *in vacuo*) will fall together. But in the air the feather will remain far behind the coin, because nearly all the atoms of the former are resisted by the air, while in the coin only some particles are exposed to the resistance, the *density* of the latter preventing the air from reaching more than a few atoms, comparatively speaking. The theory of weight and gravitation, and experiments relating to the falling of bodies, may be easily demonstrated with ordinary objects that we have at hand. I take a halfpenny and a piece of paper, which I cut in the shape of the coin, and holding them side by side, I drop them simultaneously; the halfpenny reaches the ground some time before the paper, a result quite in accordance with the laws of gravitation, as one must bear in mind the presence of air, and the different resistance it offers to two bodies differing

in density. I next place the paper disc on the upper surface of the piece of money, and then drop them simultaneously. The two objects now reach the ground at the same time, the paper, in contact with the halfpenny, being preserved from the action of the air. This experiment is so well known that we need not further discuss it; but it must be plainly evident that it is capable of development in experiments on phenomena relating to falling bodies.* When a body influenced by the action of a force acts, in its turn, upon another, the latter reacts in an opposite manner upon the first, and with the same intensity.

The attraction of Cohesion is the attraction of particles of bodies to each other at very small distances apart. Cohesion has received various names in order to express its various degrees. For instance, we say a body is tough or brittle, or soft or hard, according to the degrees of cohesion the particles exercise. We know if we break a glass we destroy the cohesion; the particles cannot be reunited. Most liquid particles can be united, but not all. Oil will not mix with water.

* M. A. G. has written us an interesting letter on the subject of similar experiments, which we here transcribe:—

"When a siphon of seltzer water has been opened some little time, and the equilibrium of tension is nearly established between the escaped gas and the dissolved gas, a vertical stream of bubbles is seen to rise from the bottom of the apparatus, which present a very clear example of the law of ascension of bubbles; that is to say (putting out of the question the expansion of the bubbles in their passage upwards), it is an inverse representation of the law of gravity affecting falling bodies. The bubbles, in fact, detach themselves from their starting point with perfect regularity; and as the interval varies in one file from another, we have before us a multiplied representation of that terrible law which Attwood's machine made such a bugbear to the commercial world. I believe it is possible, by counting the number of bubbles that detach themselves in a second, in each file, and the number which the whole stream contains at a given instant, to carry the verification further; but I must confess that I have not done so myself."

The force of cohesion depends upon heat. Heat expands everything, and the cohesion diminishes as temperature increases.

There are some objects or substances upon the earth the particles of which adhere much more closely than others, and can only, with very great difficulty, be separated. These are termed *Solids.* There are other substances whose particles can easily be divided, or their position altered. These are called *Fluids.* A third class seem to have little or no cohesion at all. These are termed *Gases.*

Adhesion is also a form of attraction, and is cohesion existing on the surfaces of two bodies. When a fluid adheres to a solid we say the solid *is wet.* We turn this natural adhesion to our own purposes in many ways,—we whitewash our walls, and paint our houses ; we paste our papers together, etc.

On the other hand, many fluids will not adhere. Oil and water have already been instanced. Mercury will not stick to a glass tube, nor will the oiled glass tube retain any water. We can show the attraction and repulsion in the following manner :—Let one glass tube be dipped into water and another into mercury, you will see that the water will ascend slightly at the side, owing to the attraction of the glass, while the mercury will be higher in the centre, for it possesses no attraction for the glass. If small, or what are termed capillary (or hair) tubes, be used, the water will rise up in the one tube, while in the other the mercury will remain lower than the mercury outside the tube. (See *Capillarity.*)

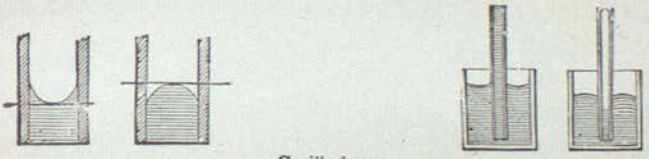
Chemical attraction is the force by which two different bodies unite to form a new and different body from either.

It is needless for us to dwell upon the uses of these Forces of Nature. Gravity and Cohesion being left out of our world, we can imagine the result. The earth and sun

and planets would wander aimlessly about; we should float away into space, and everything would fall to pieces, while our bodies would dissolve into their component parts.

The Balance and Centre of Gravity.—We have spoken at some length about Gravity, and now we must say something respecting that point called the *Centre of Gravity*, and the *Balance*, and upon the latter we have a few remarks to make first, for a well-adjusted balance is a most useful thing, and we will show you how to make one, and then proceed to our illustrations of the Centre of Gravity, and explain it.

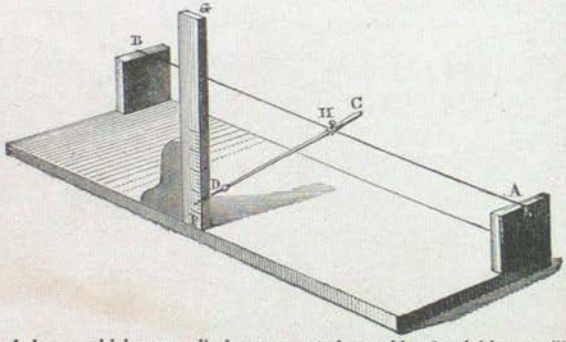
All those who cultivate experimental science are aware



Capillarity.

that it is useful to unite with theoretical ideas that manual dexterity which is acquired by the student accustoming himself to practical operations. One cannot too strongly urge both chemist and physicist to exercise themselves in the construction of the appliances they require, and also to modify those already existing, which may be adapted to their wants. In a large number of cases it is possible to manufacture, at small expense, delicate instruments, capable of rendering the same service as the most elaborate apparatus. Important scientific labours have often been undertaken by men whose laboratories were most simple, who, by means of skill and perseverance, knew how to do great things with small resources. A delicate balance, for instance, indispensable alike to chemist and physicist, can be manufactured at little cost in different ways. A thin platinum wire and a piece of wood is all that is

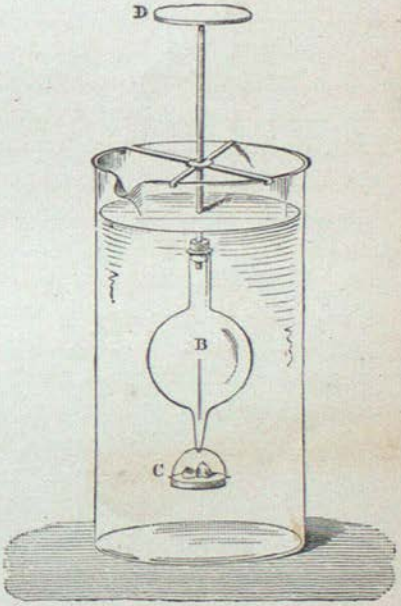
needed to make a balance capable of weighing a milligram; and to make a very sensitive hydrostatic balance, little is required besides a glass balloon. The cut represents a small torsion balance of extreme simplicity. A thin platinum wire is stretched horizontally through two staples, from the wooden supports, AB, which are fixed in a deal board. A very thin, delicate lever, CD, cut in wood, or made with a wisp of straw, is fixed in the centre of the platinum wire by means of a small clip, which secures it firmly. This lever is placed in such a manner that it is raised perceptibly out of the horizontal line. At D is fixed



Torsion balance, which can easily be constructed, capable of weighing a milligram one-tenth of full size

a paper scale, on which is put the weight of a centigram. The lever is lowered to a certain point, slightly twisting the platinum wire. Near the end of the lever a piece of wood, F, is fixed, on which is marked the extreme point of its movements. Ten equi-distant divisions are marked between these two points, which represent the distance traversed by the lever under the weight of the milligram. If a smaller weight than a centigram is placed on the paper scale the lever falls, and balances itself after a few oscillations. If it falls four divisions, it is evident that the substance weighs four milligrams. Taking a rather thicker platinum wire, to which a shorter lever must be adapted,

one can weigh the decigram, and so on. It would be an easy matter, also, to make, on the same model, balances for weighing considerable weights. The platinum wire should be replaced by iron wires of larger diameter, firmly stretched, and the lever should be made of a piece of very resisting wood. One can also, by adaptation, find the exact value of the most trifling weights. By lengthening a very fine platinum wire several yards, and adapting a long, slender lever, it will not be impossible to ascertain the tenth of a milligram. In this latter case the balance can be set when it is wanted.



Nicholson's Areometer, contrived to serve as a balance.

The next cut represents Nicholson's Areometer, which any one may construct for himself, and which, as it is here represented, constitutes another kind of balance. A glass balloon, filled with air, is hermetically closed with a cork, through which is passed a cylinder of wood, surmounted by a wooden disc, D. The apparatus is terminated at its lower end by a small tray, C, on which one can put pieces of lead in variable quantities. It is then plunged into a glass filled with water. The pieces of lead on the tray, C, are added by degrees, until the stem of the areometer rises almost entirely above the level of the water ; it is next passed through a ring, which keeps it in position, and

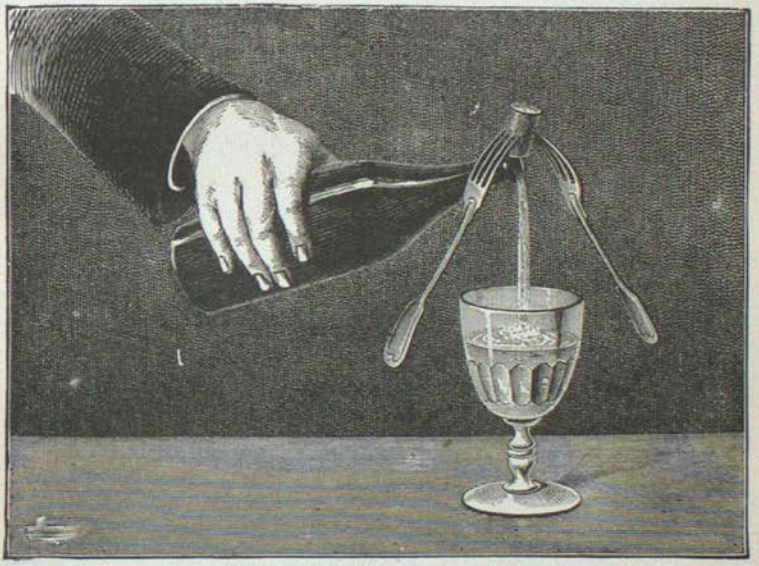
which is fastened to the upper part of the glass by means of four iron wires in the shape of a cross. The stem is divided in such a way that the space comprised in each division represents the volume of a cubic centimetre. Thus arranged, the apparatus constitutes a balance. The object to be weighed is placed on the disc, D, and the areometer sinks in the water, oscillates, and then remains in equilibrium. If the stem sinks five divisions, it is evident that the weight of the object corresponds to that of five cubic centimetres of displaced water, or five grams.

It is obvious, therefore, from the preceding examples, that it is not impossible to construct a weighing apparatus with ordinary and very inexpensive objects. We can, in the same way, show that it is possible to perform instructive experiments with no appliances at all, or, at any rate, with common things, such as everyone has at hand. The lamented Balard, whose loss science has had recently to deplore, excelled in chemical experiments without a laboratory; fragments of broken glass or earthenware were used by him for improvising retorts, bottles and vases for forming precipitates, and carrying on many important operations.

Scheele also operated in like manner; he knew how to make great discoveries with the humblest appliances and most slender resources. One cannot too earnestly endeavour to imitate such leaders, both in teaching others and instructing oneself.

The laws relating to the weight of bodies, the centre of gravity, and stable or unstable equilibrium, may be easily taught and demonstrated by means of a number of very familiar objects. By putting into the hands of a child a box of soldiers cut in elder-wood, the end of each fixed into half a bullet, we provide him with the means of making some easy experiments on the centre of gravity. According to some authorities on equilibrium, it is not

impossible, with a little patience and delicacy of manipulation, to keep an egg balanced on one of its ends. This experiment should be performed on a perfectly horizontal surface, a marble chimney-piece, for example. If one can succeed in keeping the egg up, it is, according to the most elementary principles of physics, because the vertical line of the centre of gravity passes through the point of

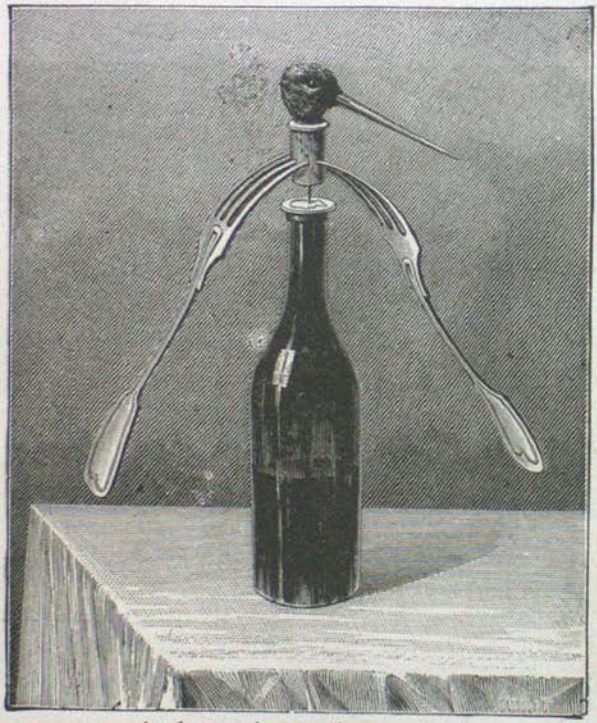


Experiment on "centre of gravity."

contact between the end of the egg and the surface on which it rests.

Here is a curious experiment in equilibrium, which is performed with great facility. Two forks are stuck into a cork, and the cork is placed on the brim of the neck of a bottle. The forks and the cork form a whole, of which the centre of gravity is fixed over the point of support. We can bend the bottle, empty it even, if it contains fluid, without the little construction over its mouth being in the least

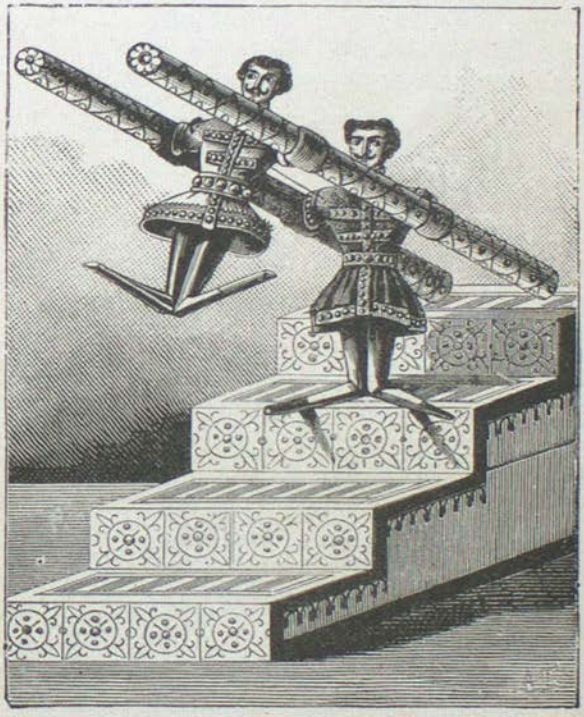
disturbed from its balance. The vertical line of the centre of gravity passes through the point of support, and the forks oscillate with the cork, which serves as their support, thus forming a movable structure, but much more stable than one is inclined to suppose. This curious experiment



Another experiment on the same subject.

is often performed by conjurors, who inform their audience that they will undertake to empty the bottle without disturbing the cork. If a woodcock has been served for dinner, or any other bird with a long beak, take off the head at the extreme end of the neck ; then split a cork so that you can insert into it the neck of the bird, which must be tightly clipped to keep it in place ; two forks are

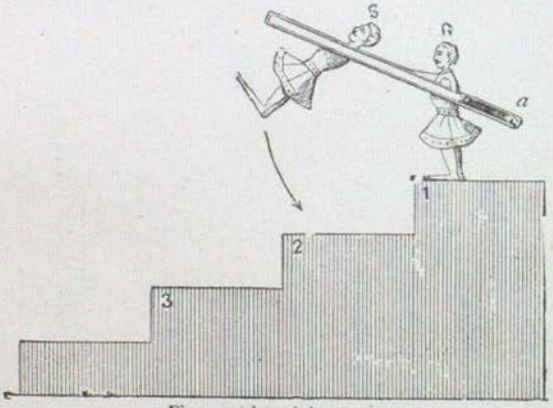
then fixed into the cork, exactly as in the preceding example, and into the bottom of the cork a pin is inserted. This little contrivance is next placed on a piece of money, which has been put on the opening of the neck of the bottle, and when it is fairly balanced, we give it a rotatory



Automatic puppets.

movement, by pushing one of the forks as rapidly as we please, but as much as possible without any jerk. We then see the two forks, and the cork surmounted by the woodcock's head, turning on the slender pivot of a pin. Nothing can be more comical than to witness the long beak of the bird turning round and round, successively facing all the company assembled round the table, some-

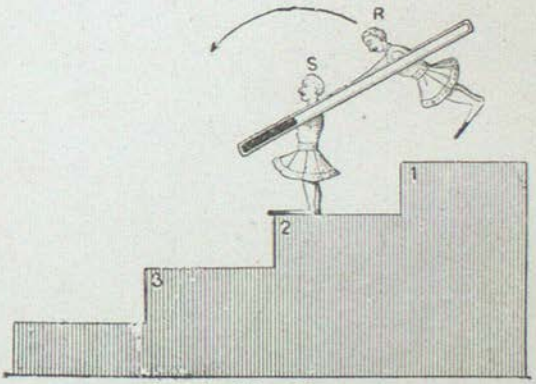
times with a little oscillation, which gives it an almost life-like appearance. This rotatory movement will last some time, and wagers are often laid as to which of the company the beak will point at when it stops. In laboratories, wooden cylinders are often to be seen which will ascend an inclined plane without any impulsion. This appears very surprising at first, but astonishment ceases when we perceive that the centre of gravity is close to the end of the cylinder, because of a piece of lead, which has been fixed in it.



First position of the puppets.

Above is a very exact representation of a plaything which was sold extensively on the Boulevards at Paris. This little contrivance, which has been known for some time, is one of the most charming applications of the principles relating to the centre of gravity. With a little skill, any one may construct it for himself. It consists of two little puppets, which turn round axles adapted to two parallel tubes containing mercury. When we place the little toy in the position as above, the mercury being at *a*, the two dolls remain motionless, but if we lower the doll S, so that it stands on the second step (No. 2) of the flight, as indicated in the second cut, the mercury descends to *b* at the

other end of the tube ; the centre of gravity is suddenly displaced ; the doll R then accomplishes a rotatory movement, as shown by the arrow in the third cut, and finally alights on step No. 3. The same movement is also effected by the doll S, and so on, as many times as there are steps. The dolls may be replaced by a hollow cylinder of cartridge paper closed at both ends, and containing a marble ; the cylinder, when placed vertically on an inclined plane, descends in the same way as the puppets. The laws of equilibrium and displacement of

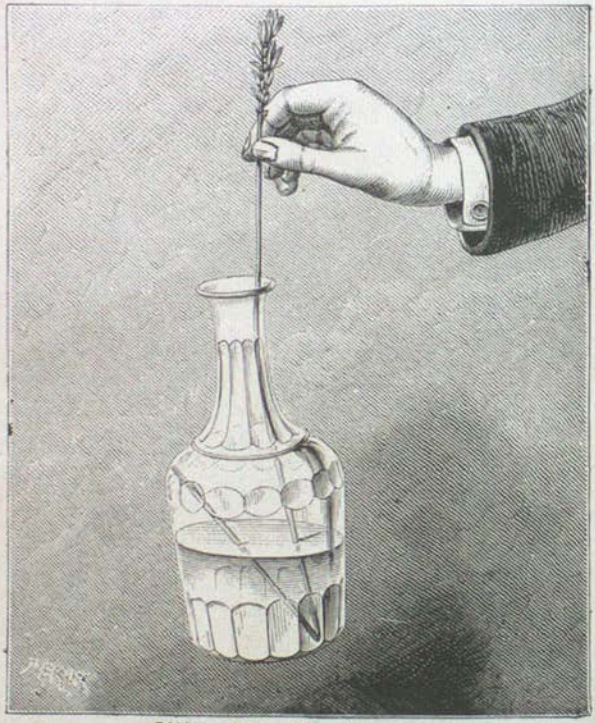


Second position of the puppets.

the centre of gravity, are rigorously observed by jugglers, who achieve many wonderful feats, generally facilitated by the rotatory motion given to the bodies on which they operate, which brings into play the centrifugal force. The juggler who balances on his forehead a slender rod, on the end of which a plate turns round, would never succeed in the experiment if the plate did not turn on its axis with great rapidity. But by quick rotation the centre of gravity is kept near the point of support. We need hardly remark, too, that it is the motion of a top that tends to keep it in a vertical position.

Many experiments in mechanical physics may occur

to one's mind. To conclude the enumeration of those we have collected on the subject, I will describe the method of lifting a glass bottle full of water by means of a simple wisp of straw. The straw is bent before being passed into the bottle of water, so that, when it is lifted, the

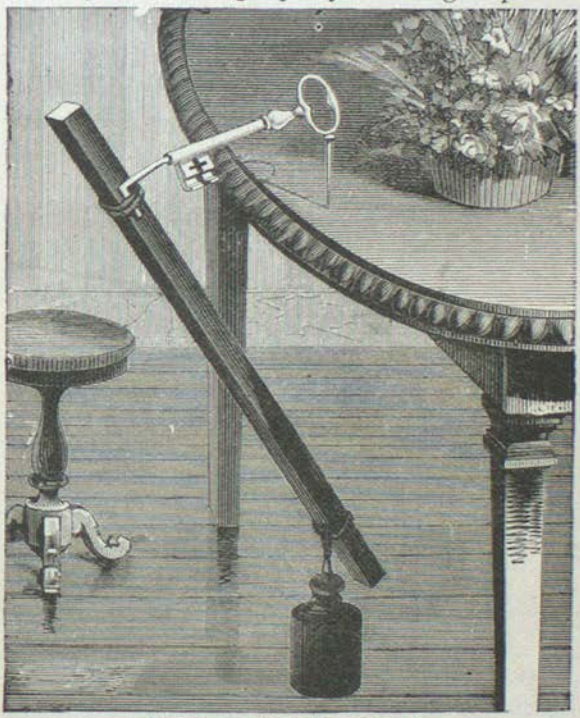


Lifting a bottle with a single straw.

centre of gravity is displaced, and brought directly under the point of suspension. It is well to have at hand several pieces of straw perfectly intact, and free from cracks, in case the experiment does not succeed with the first attempt.

Having now seen how this point we call the centre of gravity acts, we may briefly explain it.

The centre of gravity of a body is that point in which the sum of the forces of gravity, acting upon all the particles, may be said to be united. We know the attraction of the earth causes bodies to have a property we call *Weight*. This property of weight presses upon

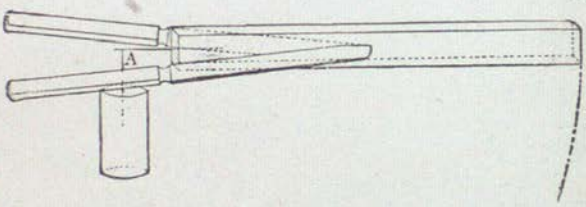


Balancing a weight on a nail and key.

every particle of the body, and acts upon them as parallel forces. For if a stone be broken all the portions will equal the weight of the stone; and if some of them be suspended, it will be seen that they hang parallel to each other, so we may call these weights parallel forces united in the whole stone, and equal to a single resultant. Now to find the centre of gravity, we must suspend the body,

and it will hang in a certain direction. Draw a line from the point of suspension, and suspend the body again: a line drawn from that point of suspension will pass through the same place as the former line did, and so on. That point is the centre of gravity of that suspended body. If the form of it be regular, like a ball or cylinder, the centre of gravity is the same as the mathematically central point. In such forms as pyramids it will be found near the largest mass; viz., at the bases, about one-fourth of the distance between the apex and the centre of gravity of the base.

When the centre of gravity of any body is supported, that body cannot fall. So the well-known leaning towers



Another experiment.

are perfectly safe, because their lines of direction fall within the bases. The centre of gravity is in the centre of the leaning figure. The line of direction drawn vertically from that point falls within the base; but if the tower were built up higher, so that the centre of gravity were higher, then the structure would fall, because the line of direction would fall without the base.

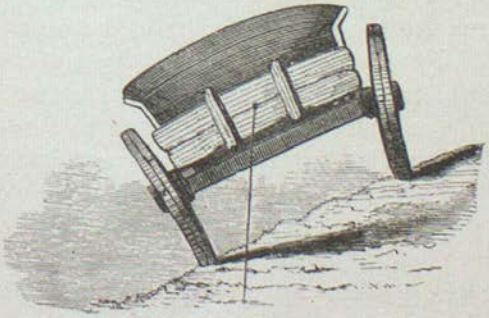
We see that animals (and men) are continually altering the position of the centre of gravity; for if a man bears a load he will lean forward, and if he takes up a can of water in one hand he will extend the other to preserve his balance or equilibrium.

The experiment shown in the foregoing illustration is apparently very difficult, but it will be found easy

enough in practice if the hand be steady. Take a key, and by means of a crooked nail or "holdfast," attach it to a bar of wood by a string tied tightly round the bar, as in the picture. To the other extremity of the bar attach a weight, and then drive a large-headed nail into the table. It will be found that the key will balance, and even move upon the head of the nail, without falling. The weight is under the table, and the centre of gravity is exactly beneath the point of suspension.

Another simple experiment may prove amusing. Into a piece of wood insert the points of two knives, and at the centre of the end of the bar insert a needle between the knife handles. The wood and the knives may then be balanced on another needle fixed in a cork at A.

We may conclude this chapter by summing up in a few words what the Centre of Gravity is. We can define it as "that point in a body upon which the body, acted on solely by the force of gravity, will balance itself in all positions." Such a point exists in every body, and equally in a number of bodies fastened tightly together. The Centre of Gravity has by some writers been denominated the *Centre of Parallel Forces*, or the *Centre of Magnitude*, but the Centre of Gravity is the most usual and best understood term.



CHAPTER IV.—SOLID BODIES.

SOME PROPERTIES OF SOLID BODIES—INERTIA—MOTION —FRICTION—THE PENDULUM—EQUILIBRIUM.

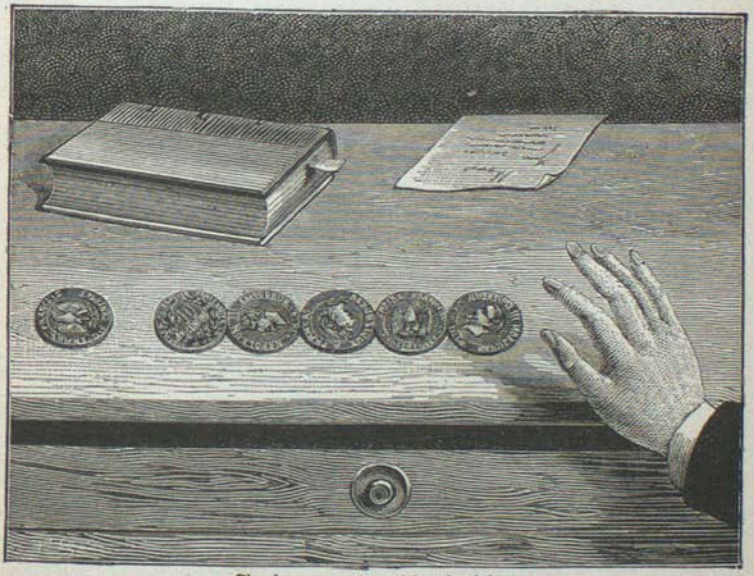
THOSE who have followed us through the preceding pages have now, we hope, some ideas upon Gravity and the Forces of Nature. In speaking of Forces we said "Force was a cause of Motion." Let us now consider Inertia, and Motion with its accompanying opponent, Friction.

INERTIA is the passiveness of Matter. This perfect indifference to either rest or motion makes the great distinction between living and lifeless matter. Inertia, or *Vis Inertia*, is this passiveness. Now, to overcome this indifference we must use force, and when we have applied force to matter we set it in motion ; that is, we move it. When we move it we find a certain resistance which is always proportionate to the force applied. In mechanics this is termed *Action*, and *Reaction*, which are always equal forces acting in opposite directions. This is Newton's law, and may be explained by a "weight" on a table, which presses against the table with the same force with which the table presses against the "weight"; or when you strike a ball, it strikes the hand with the same force.

We can communicate motion by elasticity. For instance, if we place a number of coins upon a table touching each other and in a straight line, and strike the last coin of the line by pushing another sharply against it. the piece

at the opposite extremity will slip out of its place from the effect of the shock transmitted by the coin at the other end.

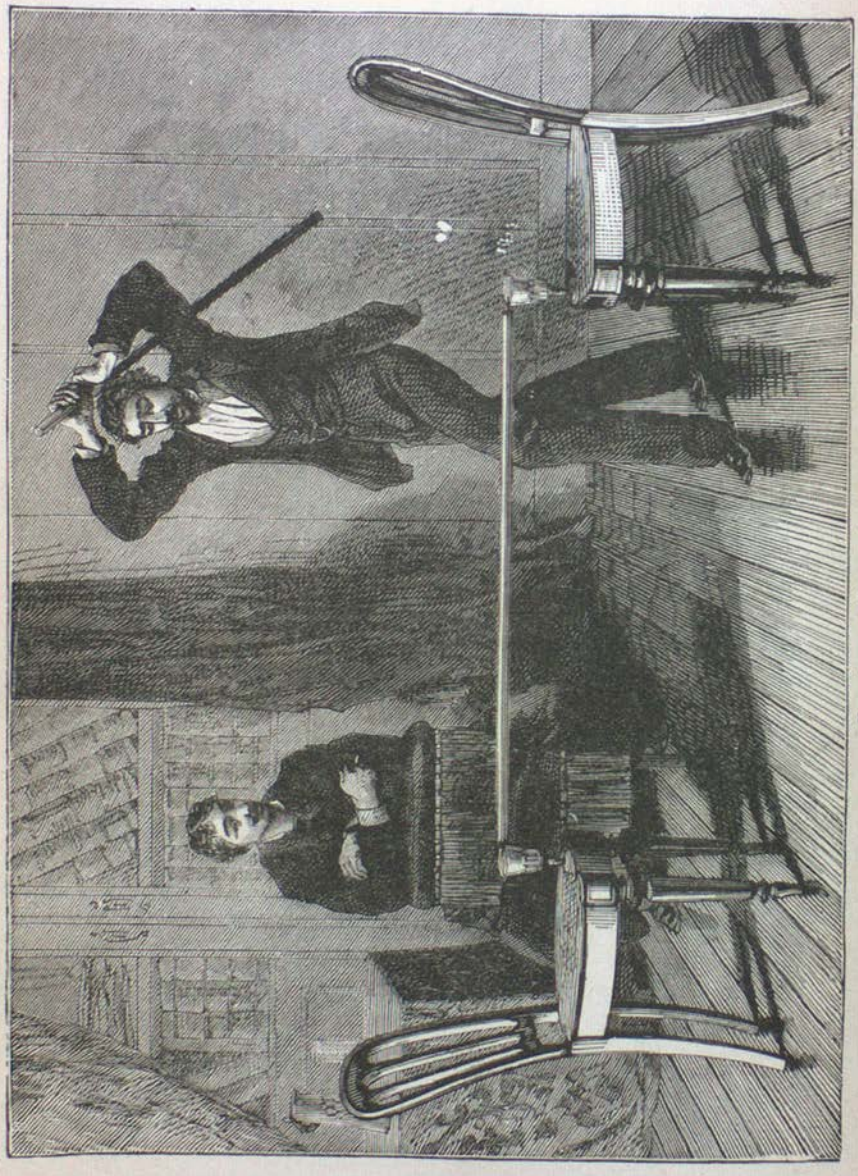
When two forces act upon a body at the same time, it takes a direction intermediate. This is known as the resultant. The enormous forces exercised by the heavenly bodies will be treated of later. We will first consider *Inertia.*



Shock communicated by elasticity.

There are several experiments relating to the subject of Inertia which may be performed. I once witnessed one quite accidentally when taking a walk.

I was one day passing the Observatory at Paris, when I noticed a number of people collected round a professor, who after executing several juggling tricks, proceeded to perform the curious experiment I am about to describe. He took a broomstick and placed it horizontally, passing the ends through two paper rings. He then asked two



Experiment to illustrate inertia.

children to hold the paper rings by means of two razors, so that the rings rested on the blade. This done, the operator took a stout stick, and, with all his strength, struck the broomstick in the centre; it was broken into shivers, but the paper rings were not torn in the least, or



Another experiment on the same subject.

even cut by the razors! One of my friends, M. M——, a painter, showed me how to perform this experiment as represented in the illustration. A needle is fixed at each end of the broomstick, and these needles are made to rest on two glasses, placed on chairs; the needles alone must be in contact with the glasses. If the broomstick is then struck violently with another stout stick, the former will be

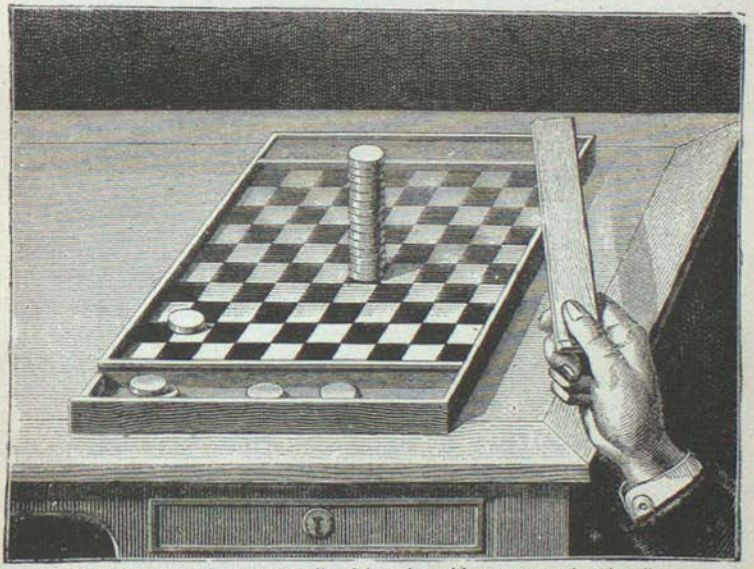
broken, but the glasses will remain intact. The experiment answers all the better the more energetic the action. It is explained by the resistance of inertia in the broomstick. The shock suddenly given, the impulse has not time to pass on from the particles directly affected to the adjacent particles; the former separate before the movement can be transmitted to the glasses serving as supports.*

The experiment next represented is of the same nature. A wooden ball is suspended from the ceiling by a rather slender thread, and a similar thread is attached to the lower end of the ball. If the lower thread is pulled forcibly it will break, as shown in the illustration; the movement communicated to it has not time to pass into the ball; if, on the contrary, it is pulled very gradually and without any shock, the upper thread instead will break, because in this case it supports the weight of the ball. Motion is not imparted simultaneously to all parts of a body, but only to the particles first exposed to a blow, for instance. One might multiply examples of this. If a

* The experiment we have just described is a very old one. M. V. Sircoulon has told us that it was described at length in the works of Rabelais. The following remarks are in "Pantagruel," book II., chap. xvii.

"Panurge then took two glasses of the same size, filled them with water, and put one on one stool, and the other on another, about five feet apart, and placed the staff of a javelin about five-and-a-half feet long across, so that the ends of the staff just touched the brim of the glasses. That done, he took a stout piece of wood, and said to the others: 'Gentlemen, this is how we shall conquer our enemies; for in the same way that I shall break this staff between these two glasses, without the glasses being broken or injured, or spilling a single drop of water, so shall we break the head of our Dipsodes, without any injury to ourselves, and without getting wounded. But that you may not think there is magic in it, you, Eusthenes, strike with this stick as hard as you can in the centre.' This Eusthenes did, and the staff broke in two pieces, without a drop of water being spilt."

bullet be shot from a gun, it will make a round hole in a piece of wood or glass, whilst if thrown by the hand,—that is to say, with much less force,—it will shiver the wood or the pane of glass to pieces. When the celerity of the motive force is very great, the particles directly affected are disturbed so quickly that they separate from the adjacent particles before there is time for the movement to be communicated to the latter.

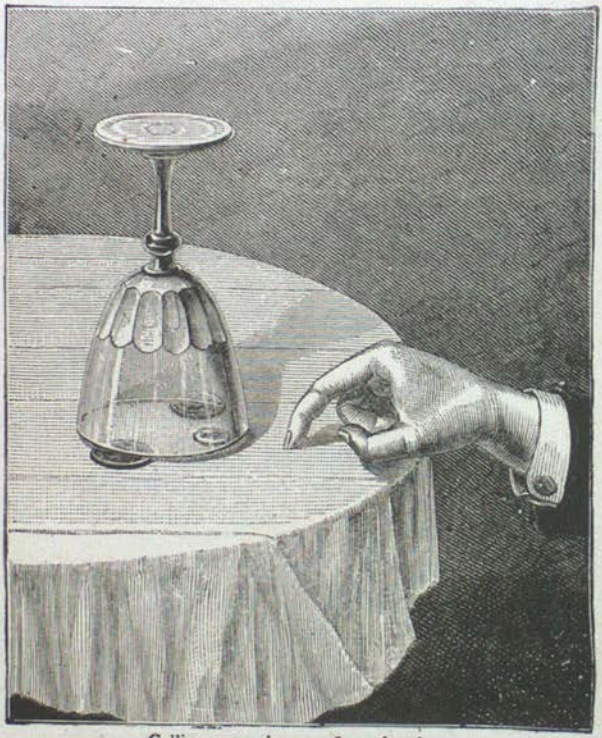


Extracting a "man" from a pile of draughts without overturning the pile.

It is possible, for the same reason, to extract from a pile of money a piece placed in the middle of the pile without overturning the others. It suffices to move them forcibly and quickly with a flat wooden ruler. The experiment succeeds very well also if performed with draughtsmen piled up on the draught-board.

Another experiment which belongs to the laws of resisting force is herewith shown. A sixpence is placed

on a table covered with a cloth or napkin. It is covered with a glass, turned over so that its brim rests on two penny pieces. The problem to be solved is how to extract the sixpence from underneath the glass without touching it, or slipping anything beneath it. To do this

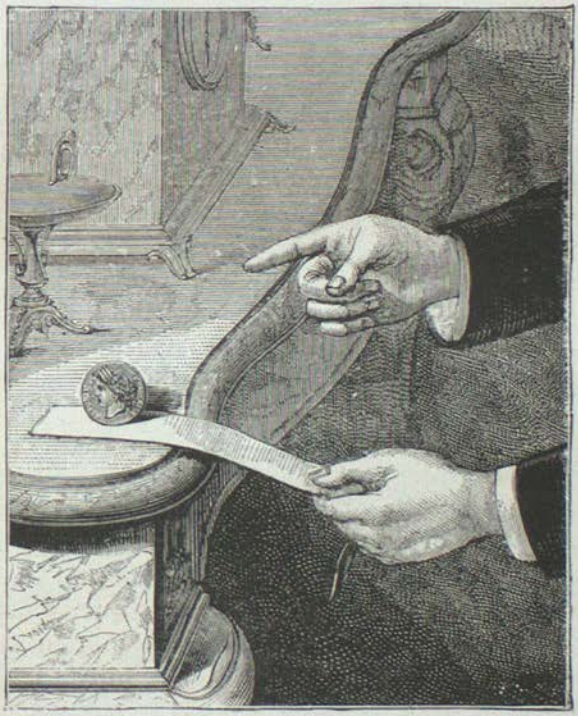


Calling out a sixpence from the glass.

it is necessary to scratch the cloth with the nail of the forefinger; the elasticity of the material communicates the movement to the sixpence, which slowly moves in the direction of the finger, until it finally comes out completely from beneath the glass.

We may give another experiment concerning Inertia. Take a strip of paper, and upon it place a coin, on a

marble chimney-piece, as in the illustration. If, holding the paper in the left hand, you strike it rapidly and forcibly, you will be enabled to draw away the paper without causing the coin (say a five-shilling-piece) to fall down.



Drawing a slip of paper from beneath a coin.

It is not impossible to draw away a napkin laid as a tablecloth for one person's dinner, without disturbing the various articles laid upon it. A quick motion is all that is necessary, keeping the napkin tightly extended by the hands at the same time. This latter experiment, however, is not recommended to boys home for the holidays, as they

may unwillingly practise a feat analogous to that executed by Humpty-Dumpty, and find equal difficulty to match the pieces.

We will now examine the term *Motion.* A body is said to be in motion when it changes its position in relation to surrounding objects. To perceive motion the surrounding objects must be relatively at rest, for if they all hurried along at the same rate no motion would be perceptible. This is evident, for when we stand still trees and houses appear stationary, as do we ourselves, but we know we all are rushing round with the earth, though our *relative* positions are unchanged. Hence there is no *absolute* rest.

What are the causes of motion?—Gravity is one. The influence of heat, which is itself caused by the motion of atoms, the effects of electricity, etc., and finally, the power of force in men or animals—any of these causes will produce motion. But a body at rest cannot put itself in motion, nor can a body in motion stop itself, or change its condition of motion.

But you may say a body will stop itself. Your ball on the ground, or even upon ice, will eventually come to a stop. We fire a bullet, and it will stop in time. We reply it does not stop of itself. The resistance of the Air and Friction tend to bring the body in motion to a state of rest. In the case of a bullet gravity brings it down.

There is no need to insist upon the resistance offered by the air even when it is not rushing violently past to fill up a vacuum beyond us, and called a breeze, or high wind. But we may say something of *Friction.*

Friction is derived from the Latin *frico,* to rub, and expresses the resistance to motion which arises from uneven surfaces. It is a passive resistance, and depends upon the force which keeps the bodies together. Thus a train running upon a smooth iron rail would never be able

to proceed but for friction, which gives the necessary purchase or grip to the wheel and rail in contact.

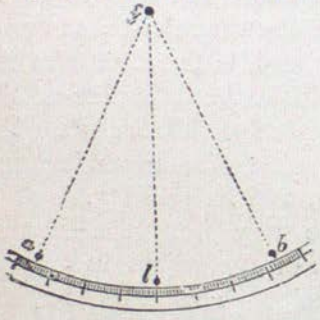
No surface is perfectly smooth, for we must push a body upon the smoothest surface we possess. Friction tends to resist motion always, and is the cause of a great loss of power in mechanics, though it is employed to stop motion by certain appliances, such as "breaks" and "drags," for sliding friction is greater than rolling friction. But without friction most structures would fall to pieces, and all forward motion would cease. So though it is an inconvenient force to overcome, we could not do without it.

If a body is set in motion, we see that the tendency of it is to go on for ever. Such, indeed, is the case with the stars; but so long as we are within the influence of the earth's attraction, we cannot expect such a result. We know now what motion is; we must also, to understand it perfectly, consider its direction and its velocity.

The line which indicates the way from the starting point to the end is the *direction* of the object in motion, and the rate it moves at its *velocity*. The latter is calculated at so many miles an hour, as a train; or so many feet in a second if the object be a shot, or other very rapidly-moving body. In equal velocity the same distance is traversed in the same time; and so if a train run a mile in a minute, we know it will travel sixty miles in an hour, and is therefore during that minute going at *the rate* of sixty miles an hour. We have already spoken of the velocity of a stone falling from a cliff as sixteen feet in a second, and a stone thrown into the air to rise sixteen feet will be a second in going up, and a second in descending. But the velocity will be accelerated in the descent after the first second of time, and retarded in the upward cast by gravity. So we have two terms—*accelerated* and *retarded* velocity—used to express an increased or decreased force of attraction.

Perpetual motion has often been sought, but never discovered, nor will it ever be till the elixir of life has been found. It is quite impossible to construct any machine that will work without friction; if any work be done energy will be expended and transformed into other energy, so the total must be diminished by so much as was employed to transform the remainder. No body can give unlimited work, therefore the perpetual motion theory is untenable and impossible.

The *pendulum* is considered the nearest approach to perpetual motion. This is so well known that no description is needed, but we may say a few words concerning it. By the diagram, we see that if we lift the ball to *b*, and let it fall, it will descend to *l*, and pass it to *a* opposite, nearly as far from *l* as *b* is from it. So the oscillations will continue, each beat being less and less, till rest is reached by the action of gravity. Were it not for friction and the pressure of the air, the oscillations would continue for ever; as it is, it declines by shorter swings till it remains in equilibrium.

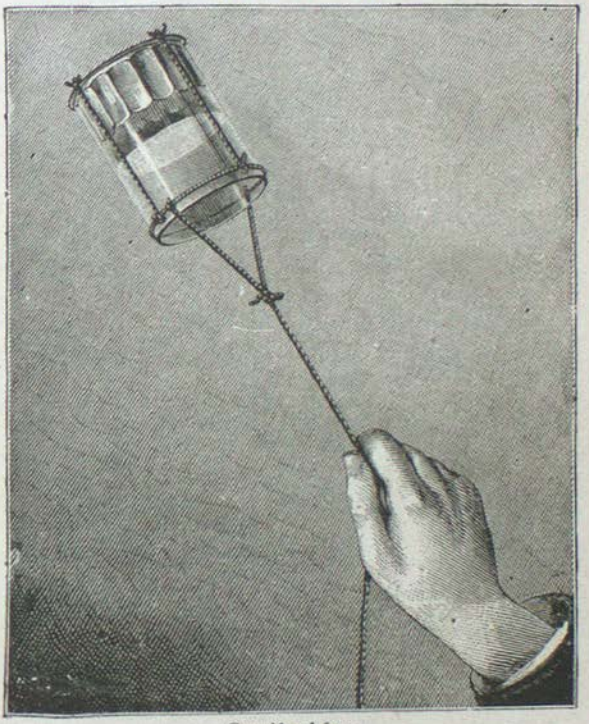


The pendulum.

The seconds' pendulum oscillates sixty times an hour, and must be of a certain length in certain places. In London it is 39·1393 inches, and furnishes a certain standard of length, and by an Act of Parliament the yard is divided into 36 parts, and 39·1393 such parts make the seconds' pendulum in the latitude of London (*in vacuo*) in a temperature of 62°.

But the same pendulum will not perform the same number of oscillations in one minute in all parts of the globe. At the equator they will be less, and at the pole

more. Thus it was discovered that, as the movements of the pendulum are dependent upon the force of gravity, and as this force decreases the farther we get from the centre of the earth, the equator must be farther from the earth's centre than the poles, and therefore the poles must



Centrifugal force.

be depressed. The decline of the pendulum at the equator is also, in a measure, due to Centrifugal Force.

Centrifugal Force, which means "flying from the centre," is the force which causes an object to describe a circle with uniform velocity, and fly away from the centre; the force that counteracts it is called the *centripetal* force. A very simple experiment will illustrate it.

To represent its action we shall have recourse to an ordinary glass tumbler placed on a round piece of cardboard, held firmly in place by cords. Some water is poured in the glass, and we then show that it can be swung to



Another illustration of centrifugal force.

and fro and round without the water being spilt, even when the glass is upside down.

Another experiment on the same subject is as shown in the above illustration, by which a napkin ring can be kept in revolution around the forefinger, and by a continued force the ring may be even held suspended at the tip of the finger, apparently in the air, without support.

CHAPTER V.—GASES AND LIQUIDS.

PRESSURE OF THE AIR—EXPERIMENTS—THE MAGDEBURG HEMISPHERES—AIR-PUMPS—THE BAROMETER—THE PUMP.

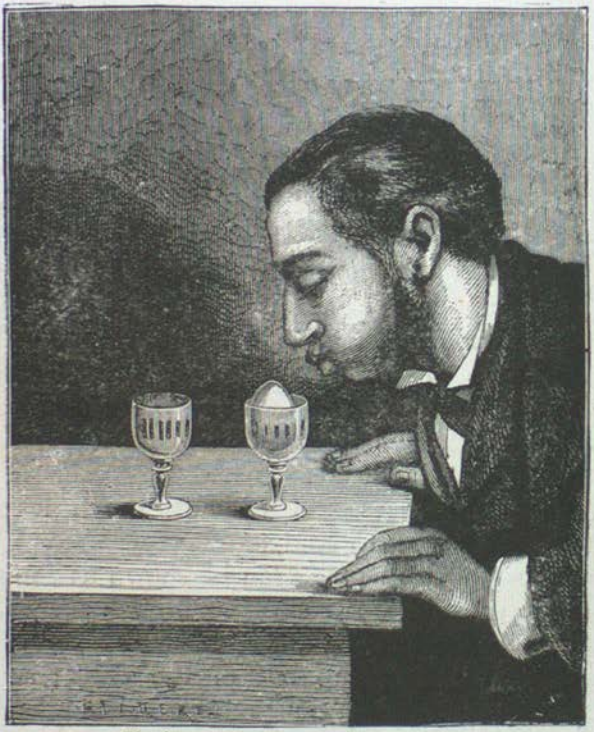
WE have more than once referred to the pressure of the air which exerts a great influence upon bodies in motion, but a few experiments will make this more obvious, and clearly demonstrate the fact. We have also told you some of the properties of Solids, such as Weight, Inertia, Friction, and Resistance, or Strength. Solids also, as we have seen, occupy space, and cannot be readily compressed, nor bent to other shapes. Now the subject of the Pressure of the Air leads us to the other forms of Matter; namely, Gases and Liquids, which it will be found very interesting to study.

The force of air can very soon be shown as acting with considerable pressure upon an egg in a glass. By blowing in a claret glass containing a hard-boiled egg, it is possible to cause the egg to jump out of the glass; and with practice and strength of lungs it is not impossible to make it pass from one glass to another, as per illustration.

The force of heated air ascending can also be ascertained by cutting up a card into a spiral, and holding it above the flame of a lamp. The spiral, if lightly poised, will turn round rapidly.

Now let us turn to a few experiments with the air, which is composed in two gases, Oxygen and Nitrogen, of which we shall hear more when we learn CHEMISTRY.

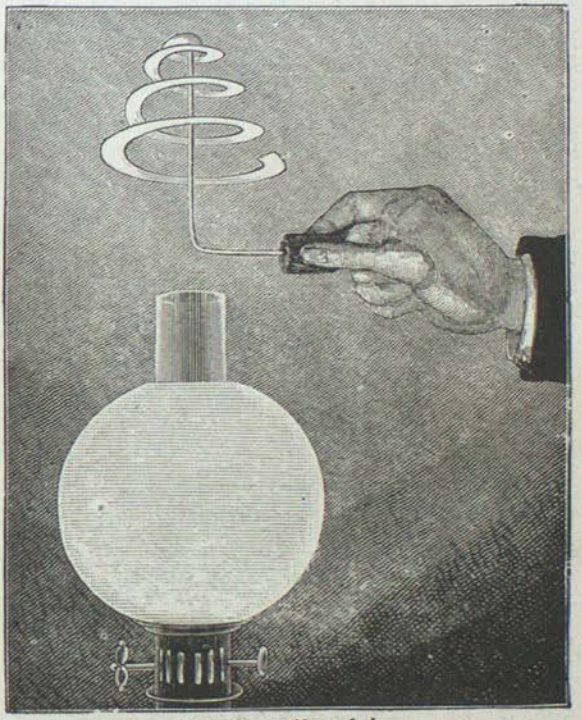
It is not intended here to prosecute researches, but rather to sketch a programme for instruction, based on amusing experiments in Physics, performed without apparatus. The greater part of these experiments are probably well known, and we desire to say that we



Blowing an egg from one glass to another.

merely claim to have collected and arranged them for our descriptions. We must also add that we have performed and verified these experiments; the reader, therefore, can attempt them with every certainty of success. We will suppose that we are addressing a young auditory, and continue our course of Physics

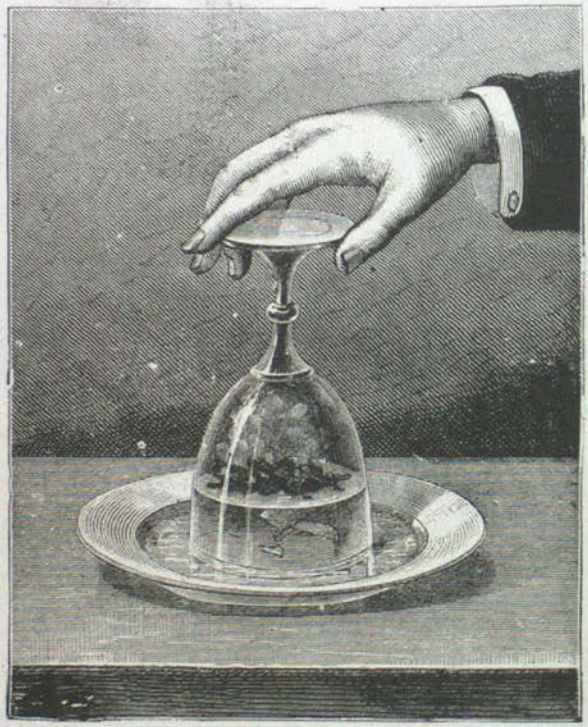
with some facts relating to the pressure of air. A wine-glass, a plate, and water, will serve for our first experiments. Pour some water on the plate, light a piece of paper resting on a cork, and cover the flame with the glass which I turn upside down. What follows?—



Movement of heated air

The water rises in the glass. Why?—Because the burning of the paper having absorbed a part of the oxygen, and the volume of confined gas being diminished, the pressure of the outer air has driven back the fluid. I next fill a goblet with water up to the brim, and cover it with a sheet of paper which touches both the edge of the glass and the surface of the water. I turn the glass

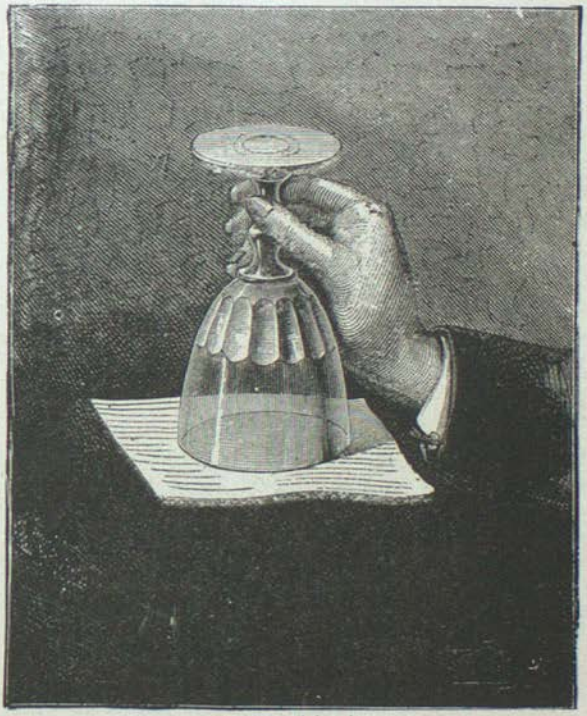
upside down, and the sheet of paper prevents the water running out, because it is held in place by atmospheric pressure. It sometimes happens that this experiment does not succeed till after a few attempts on the part of the operator; thus it is prudent to turn the glass over a



Pressure of the air.

basin, so that, in case of failure, the water is not spilt. Having obtained a vase and a bottle, both quite full of water, take the bottle, holding it round the neck so that the thumb can be used as a stopper, then turn it upside down, and pass the neck into the water in the vase. Remove your thumb, or stopper, keeping the bottle in

a vertical position, and you will see that the water it contains does not escape, but remains in suspension. It is atmospheric pressure which produces this phenomenon. If, instead of water, we put milk in the bottle, or some other fluid denser than water, we shall see that the milk

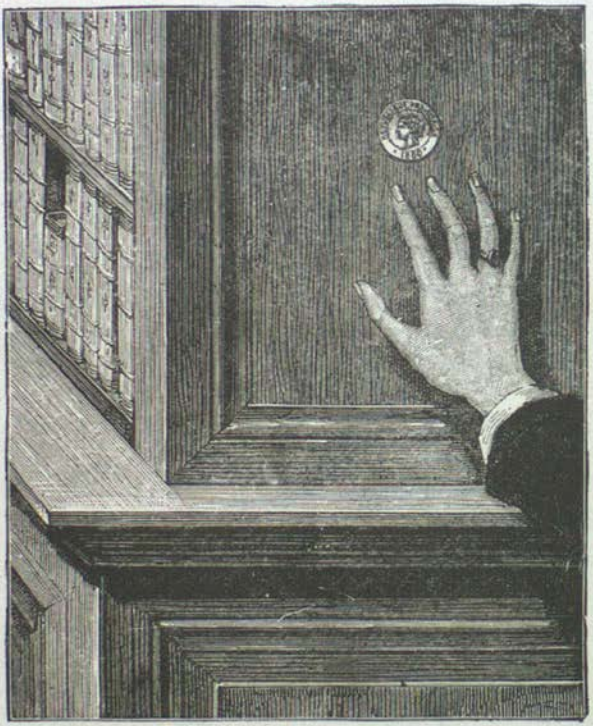


Pressure of the air.

also remains suspended in the bottle, only there is a movement of the fluid in the neck of the bottle, and on careful examination we perceive very plainly that the milk descends to the bottom of the vase, and the water rises into the bottle. Here, again, it is atmospheric pressure which maintains the fluid in the bottle, but the

milk descends, because fluids are superposed according to their order of density, and the densest liquid falls to the bottom.

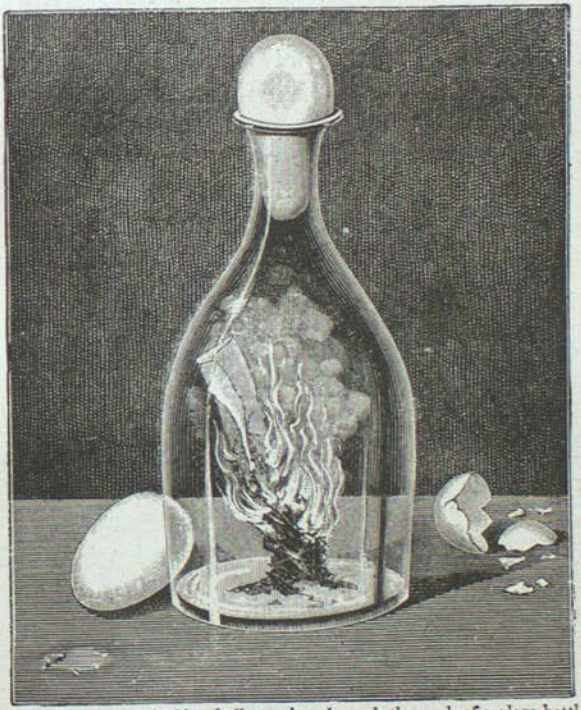
This can be verified by means of the *phial of the four elements*, which is a plain, long, and narrow bottle, containing equal volumes of metallic mercury, salt water, alcohol, and oil. These four liquids will lie one on the top of the other without ever mixing, even if shaken.



Coin adhering by pressure of air.

Another experiment as to the pressure of the air may be made. Take a penny and press it against some oaken bookcase or press, rub the coin against the wood for a few seconds, then press it, and withdraw the fingers. The

coin will continue to adhere to the wood. The reason of this is, because by the rubbing and the pressure you have dispersed the film of air which was between the penny and the wood, and under those conditions the pressure of the atmospheric air was sufficient to keep the penny in its place.



Hard-boiled egg, divested of its shell, passing through the neck of a glass bottle, under the influence of atmospheric pressure.

Or, again, let us now add a water-bottle and a hard-boiled egg to our appliances; we will make use of the air-pump, and easily perform another experiment. I light a piece of paper, and let it burn, plunging it into a water-bottle full of air. When the paper has been burning a few seconds I close the opening of the water-bottle by

means of a hard-boiled egg, which I have previously divested of its shell, so that it forms a hermetic stopper. The burning of the paper has now caused a vacuum of air in the bottle, and the egg is gradually thrust in by the atmospheric pressure outside. We see it slowly lengthening and stretching out as it passes through the aperture; then it is suddenly thrust completely into the bottle with a little explosive sound, like that produced by striking a paper bag expanded with air. This is atmospheric pressure demonstrated in the clearest manner, and at little cost.

If it is desired to pursue a little further the experiments relating to atmospheric pressure, it will be easy enough to add to the before-mentioned appliances a closed glass-tube and some mercury, and one will then have the necessary elements for performing Torricelli's and Pascal's experiments, and explaining the theory of the barometer.

An amusing toy, well-known to schoolboys, called the "sucker," may also be made the object of many dissertations on the vacuum and the pressure of air. It is composed of a round piece of soft leather, to the centre of which is attached a small cord. This leather is placed on the ground and pressed under foot, and when the cord is pulled it forms a cupping-glass, and is only separated with difficulty from the pavement.

Atmospheric air, in common with other gases, has a tendency to fill any space into which it may enter. The mutual attraction of particles of air is *nil*: on the contrary, they appear to have a tendency to fly away from each other; this property is called "repulsion." Air also possesses an expansive property—a tendency to press against all the sides of any vessel in which it may be enclosed. Of course the larger the vessel containing a given quantity of air, the less actual pressure it will exert on the sides of the vessel. The elasticity of air therefore

decreases with increasing expansion, but it gains in elasticity or force when compressed.

There is a law in Physics which expresses the relation between expansion and elasticity of gases, which may be said to be as follows :—

The elasticity (of a gas) is in inverse ratio to the space it occupies, and therefore by compressing air into a small space we can obtain a great force, as in the air-gun and the pop-gun of our youthful days.

In the cut below we can illustrate the principle of the pop-gun. The chamber full of air is closed by a cork and by an air-tight piston (S) at *p* and *p*. When the piston is pushed into the chamber the air is compressed between it and the stopper, which at length flies out forcibly with a loud report.

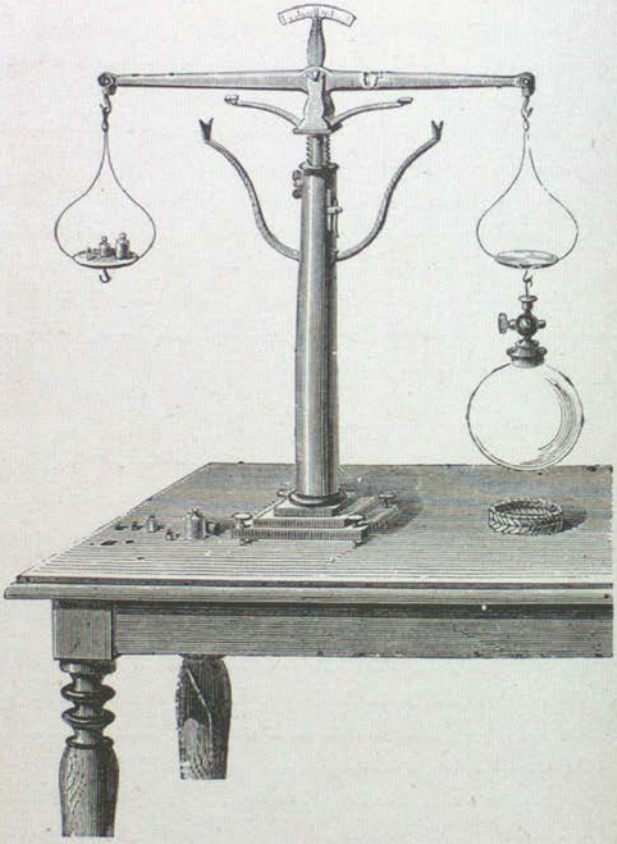


The principle of the pop-gun.

We have said that the tendency of air particles is to fly away from each other, and were it not for the earth's attraction the air might be dispersed. The height of the atmosphere has been variously estimated from a height of 45 miles to 212 miles in an attenuated form ; but perhaps 100 miles high would be a fair estimate of the height to which our atmosphere extends.

The pressure of such an enormous body of gas is very great. It has been estimated that this pressure on the average human body amounts to fourteen tons, but being balanced by elastic fluids in the body, the inconvenience is not felt. The *Weight* of Air can easily be ascertained, though till the middle of the seventeenth century the air was believed to be without weight. The following experiment will prove the weight of air. Take an ordinary

balance, and suspend to one side a glass globe fitted with a stop-cock. From this globe extract the air by means of the air-pump, and weigh it. When the exact weight is



Weighing the air.

ascertained turn the stop-cock, the air will rush in, and the globe will then pull down the balance, thus proving that air possesses weight. The experiments of Torricelli and Otto Von Guerike, however, demonstrated that the air has weight

and great pressure. Torricelli practically invented the barometer, but Otto Von Guerike, by the cups known as *Magdeburg Hemispheres*, proved the pressure of the outward air. This apparatus is well known, and consists of two hollow copper hemispheres which fit very closely. By means of the air-pump which he invented in 1650, Otto Von Guerike exhausted the air from the closed hemispheres. So long as air remained in them, there was no great difficulty in separating them ; but when it had been finally exhausted, the pressure of the surrounding atmosphere was so great that the hollow spheres could not be dragged asunder even by horses harnessed to rings which had been inserted in the globes.

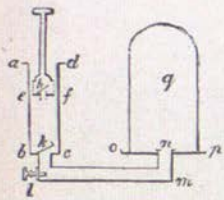


Magdeburg Hemispheres.

The *Air-Pump* is a very useful machine, and we will now briefly explain its action. The inventor was, as remarked above, Otto von Guerike, of Magdeburg. The pump consists of a cylinder and piston and rod, with two valves opening upwards—one valve being in the bottom of the cylinder, the other in the piston. This pump is attached by a tube to a plate with a hole in it, one extremity of the tube being fixed in the centre of the plate, and the other at the valve at the bottom of the cylinder. A glass shade, called the *receiver*, is placed on the top of the plate, and of course this shade will be full of air.

When the receiver is in position we begin to work the pump. We have said there are two valves. So when the piston is drawn up, the cylinder would be quite empty did not the valve at the bottom, opening upwards, admit some air from the glass shade through the tube to enter the

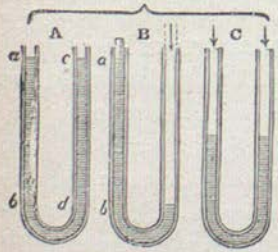
cylinder. Now the lower part of the cylinder is full of air drawn from the glass shade. When we press the piston down again, we press against the air in it, which, being compressed, tries to escape. It cannot go back, because the valve at the bottom of the cylinder won't open, so it escapes by the valve in the piston, and goes away. Thus a certain amount of air is got rid of at each stroke of the piston. Two cylinders and pistons can be used, and so by means of cog-wheels, etc., the air may be rapidly exhausted from the receiver. Many experiments are made with the assistance of the air-pump and receiver, though the air is never *entirely* exhausted from the glass.



The air-pump.

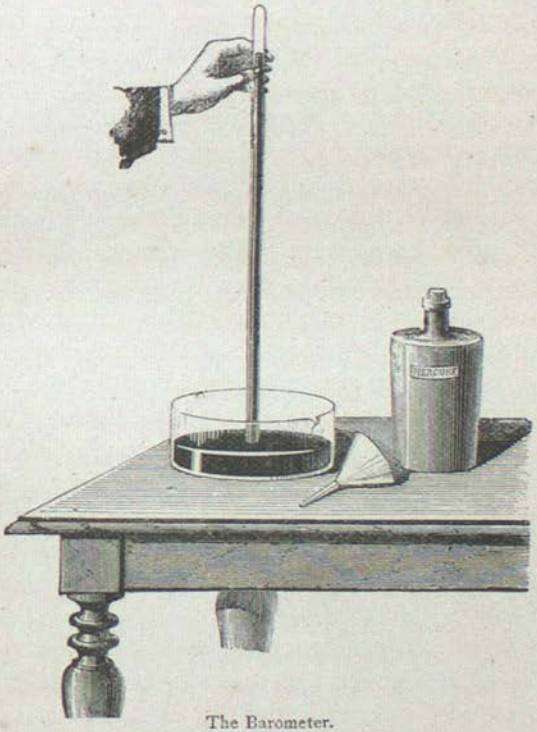
The "Sprengel" air-pump is used to create an almost perfect vacuum, by putting a vessel to be exhausted in connection with the vacuum at the top of a tube of mercury thirty inches high. Some air will bubble out, and the mercury will fall. By filling up again and repeating the process, the air vessel will in time be completely exhausted. This is done by Mr. Sprengel's pump, and a practically perfect vacuum is obtained, like the *Torricellian* vacuum.

The "Torricellian vacuum" is the empty space above the column of mercury in the barometer which we will proceed to describe. Air has a certain weight or pressure which is sufficient to raise a column of mercury thirty inches. We will prove this by illustration. Take a bent tube and fill it with mercury; the liquid will stand equally high in both arms, in consequence of the ratio of equilibrium in



Air pressure.

fluids, of which we shall read more when we come to consider Water. So the two columns of mercury are in equilibrium. (See A.) Now stop the arm *a* with a cork, and take out half the mercury. It will remain in one arm only. Remove the cork, and the fluid will fall in both



The Barometer.

arms, and remain in equilibrium. If a long bent glass tube be used, the arms being thirty-six inches high, the mercury will fall to a point, *c*, which measures 29·9 inches from the bottom. If the tube be a square inch in bore, we have 29·9 cubic inches of mercury, weighing 14$\frac{4}{5}$ lbs., balancing a column of air one square inch thick and as high as the atmosphere. So the mercury and the column of air must

weigh the same. Thus every square inch on the earth supports a weight of (nearly) 15 lbs.

The barometer invented by Pascal, working on the investigations of Torricelli, is a very simple and useful instrument. Fill a tube with mercury from which all moisture has been expelled, and turn it over in a dish of mercury: the mercury will rise to a certain height (30 inches), and no higher in vacuo. When the pressure of the air increases the mercury rises a little, and falls when the pressure is removed. Air charged with aqueous vapour is lighter than dry air, so a fall in the mercury indicates a certain amount of water-vapour in the air, which may condense and become rain. The action of mercury is therefore used as a weather-glass, by which an index-point shows the movements of the fluid, by means of a wheel over which a thread passes, sustaining a float and a counterpoise. When the mercury rises the float goes up, and the weight falls, and turns the wheel by means of the thread. The wheel having a pointer on the dial tells us how the mercury moves. This *weather-glass* is the usual *syphon barometer* with the float on the surface and a weight.

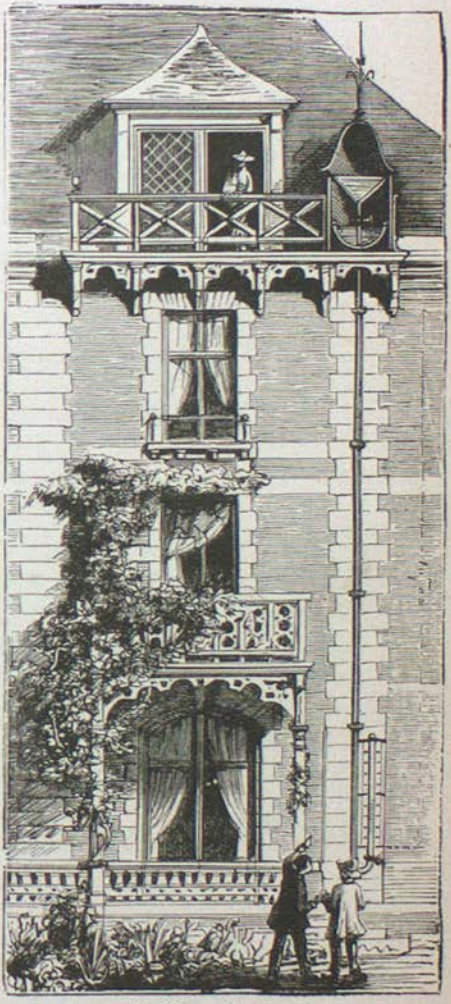


Syphon barometer.

The Syphon Barometer is a bent tube like the one already shown, with one limb much shorter than the other.

The Aneroid Barometer, so called because it is "without moisture," is now in common use. In these instruments the atmospheric pressure is held in equilibrium by an elastic metal spring or tube. A metal box, or tube, is freed from air, and then hermetically sealed. This box has a flexible side, the elasticity of which, and the pressure of the air on it, keep each other in equilibrium. Upon this elastic side the short arm of a lever is pressed, while the longer arm works an index-

point, as in the circular barometer. When pressure increases the elastic box "gives"; when pressure diminishes it returns to its former place, and the index moves in the opposite direction. It is necessary to compare and "set" the aneroid with the mercurial barometer to ensure correctness. A curved tube is sometimes used, which coils and uncoils like a spring, according to the pressure on it.



The Water Barometer.

There are other barometers, such as the Water Barometer, which can be fixed against the side of a house, and if the water be coloured, it will prove a useful indicator. As the name indicates, water is used instead of mercury, but as the latter is thirteen-and-a-half times heavier than water, a much longer tube is necessary; viz., one about thirty-five feet in length. The construction is easy enough. A leaden pipe can be fixed

against the house; on the top is a funnel furnished with a stop-cock, and placed in a vase of water. The lower part of the tube is bent, and a glass cylinder attached, with another stop-cock—the glass being about three feet long, and graduated. Fill the tube with water, shut the upper stop-cock, and open the lower one. The vacuum will be formed in the top of the tube, and the barometer will act on a larger scale than the mercury.

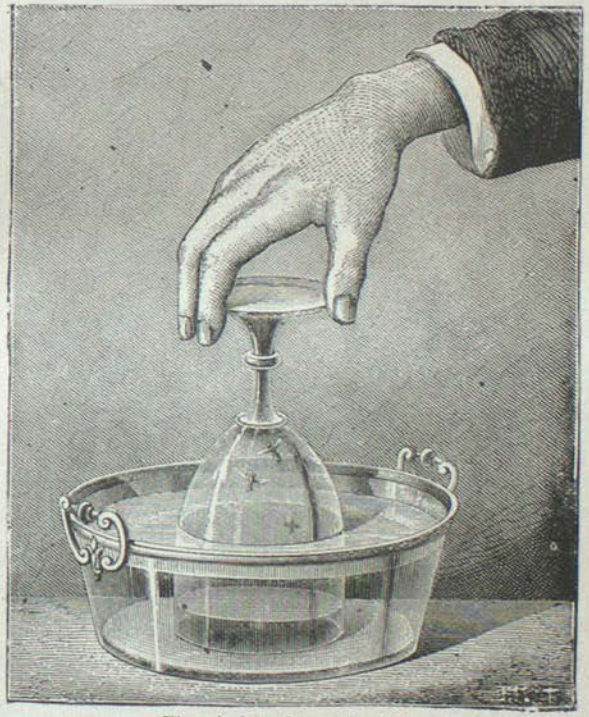
The Glycerine Barometer, invented by Mr. Jordan, and in use at the *Times* office, registers as more than one inch movements which on the mercurial thermometer are only one-tenth of an inch, and so are very distinctly visible. The specific gravity of pure glycerine is less than one-tenth that of mercury, so the mean height of the glycerine column is twenty-seven feet at sea level. The glycerine has, however, a tendency to absorb moisture from the air, but Mr. Jordan, by putting some petroleum oil upon the glycerine, neutralized that tendency, and the atmospheric pressure remains the same. A full description of this instrument was given in the *Times* of 25th October, 1880.

The uses of the barometer are various. It is employed to calculate the heights of mountains; for if a barometer at sea level stand at 30°, it will be lower on a mountain top, because the amount of air at an elevation of ten thousand feet is less than at the level of the sea, and consequently exercises less pressure, and the mercury descends. [The pressure is on the bulb of mercury at the bottom, not on the *top*, remember.]

The pressure of the air at the tops of mountains sometimes decreases very much, and it is not sufficiently dense for perfect respiration, as many people find. Some climbers suffer from bleeding at the nose, etc., at great altitudes. This is occasioned by the action of the heart, which pumps with great force, and the outward pressure

upon the little veins being so much less than usual, they give way.

Many important instruments depend upon atmospheric pressure. The most important of these is the pump, which will carry us to the consideration of water and

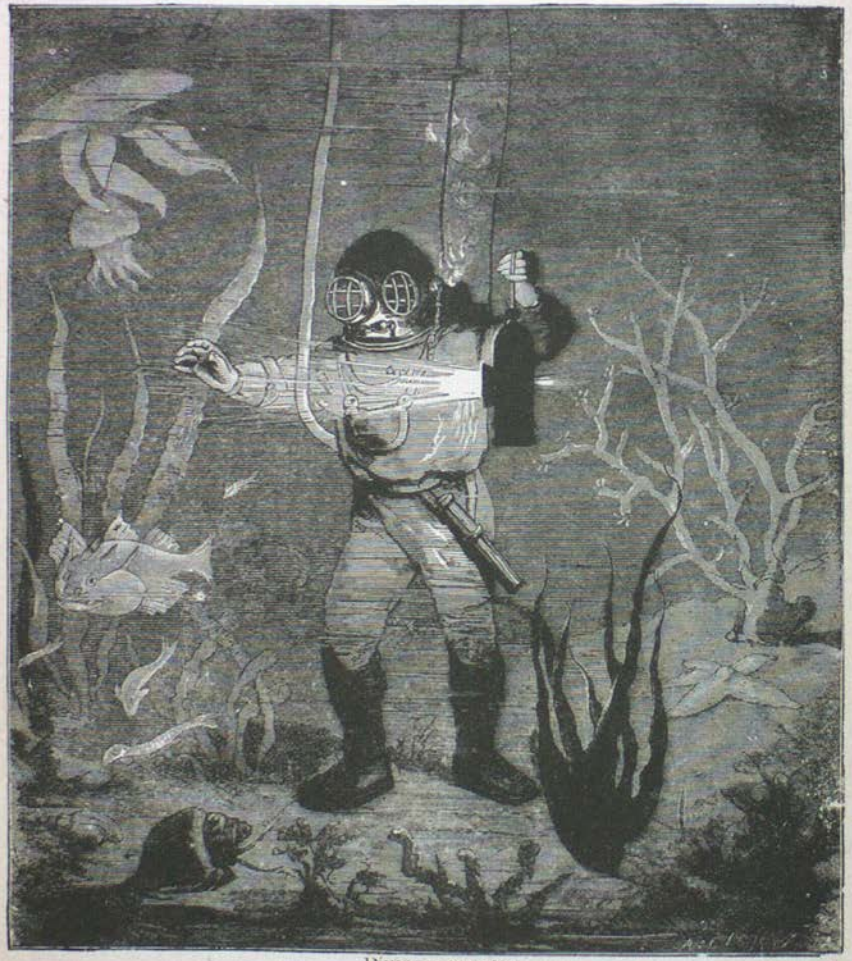


The principle of the diving-bell.

FLUIDS generally. The fire-engine is another example, but we will now proceed to explain the diving-bell already referred to.

The experiment of the diving-bell, which is so simple, is explained farther on. It belongs to the same category of experiments as those relating to the pressure of air and

compression of gas. Two or three flies have been introduced into the glass, and they prove by their buzzing



Diver under water.

about that they are quite at their ease in the rather confined space.

The DIVING-BELL in a crude form appears to have

been used as early as 1538. It was used by two Greeks in the presence of the Emperor Charles V., and numerous spectators. In the year 1720 Doctor Halley improved the diving-bell, which was a wooden box or chamber open at the bottom. Air casks were used to keep the inmate supplied with air. The modern diving-bell was used by Smeaton in 1788, and was made of cast iron. It sinks by its own weight. The pressure of the air inside is sufficient to keep the water out. Air being easily compressed, it is always pumped in to keep the hollow iron "bell" full, and to supply the workmen. There are inventions now in use by which the diver carries a supply of air with him on his back, and by turning a tap can supply himself for a long time at a distance from the place of descent, and thus is able to dispense with the air-tube from the boat at the surface. This apparatus was exhibited at the Crystal Palace some years ago.

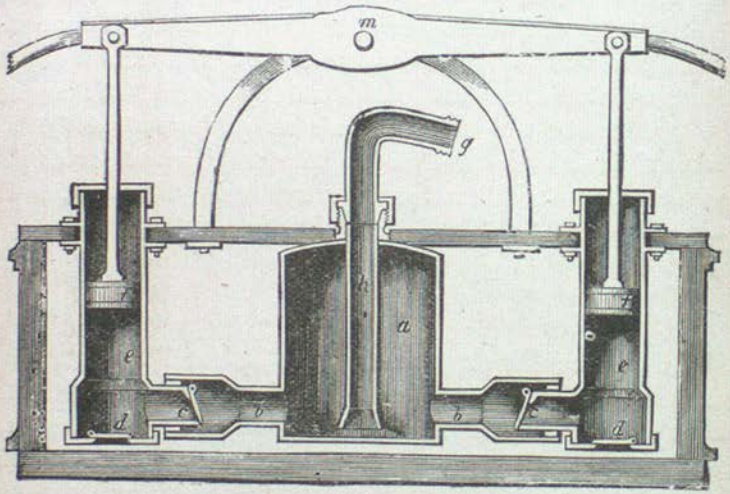
THE PUMP.

We have seen in the case of the Water Barometer that the pressure of the air will sustain a column of water about thirty feet high. So the distance between the lower valve and the reservoir or cistern must not be more than thirty-two feet, practically the distance is about twenty-five feet in pumps.

We can see by the illustration that the working is much the same as in the air-pump. The suction pipe, B, is closed by the valve, C, the cylinder, D, and spout, E, are above, the piston rod, F, lifts the air-tight piston in which is a valve, H. When the piston is raised the valve, C, opens and admits the water into the cylinder. When the piston is depressed the valve, C, is closed, the water already in forces H open, and passing through the piston, reaches the cylinder and the spout.

The hand fire-engine depends upon the action of compressed air, which is so compressed by pumping water into the air chamber, *a*. The tube is closed at *g*, and the pumps, *e e*, drive water into the air chamber. At length the tap is opened, and the air drives the water out as it is continually supplied.

Compressed air was also used for driving the boring machines in the Mount Cenis tunnel. In this case also

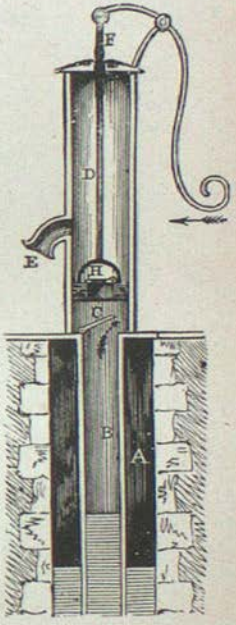


The Hand Fire-Engine

the air was compressed by water, and then let loose, like steam, to drive a machine furnished with boring instruments.

A pretty little toy may be made, and at the same time exemplify an interesting fact in Physics. It is called the *ludion*, and it "lies in a nut shell" in every sense. When the kernel has been extracted from the shell, fasten the portions together with sealing wax, so that no water can enter. At one end, o, as in the illustration, leave a small

hole about as large as a pin's head ; fasten two threads to the sealing wax, and to the threads a wooden doll. Let a weight be attached to his waist. When the figure is in equilibrium, and will float, put it into a jar of water, and tie a piece of bladder over the top. If this covering be pressed with the finger, the doll will descend and remount when the finger is removed. By quick successive pressure the figure may be made to execute a *pas seul.* The reason of the movement is because the slight cushion of air in the upper part of the vase is compressed, and the little water thus caused to enter the nut shell makes it heavier, and it descends with the figure.

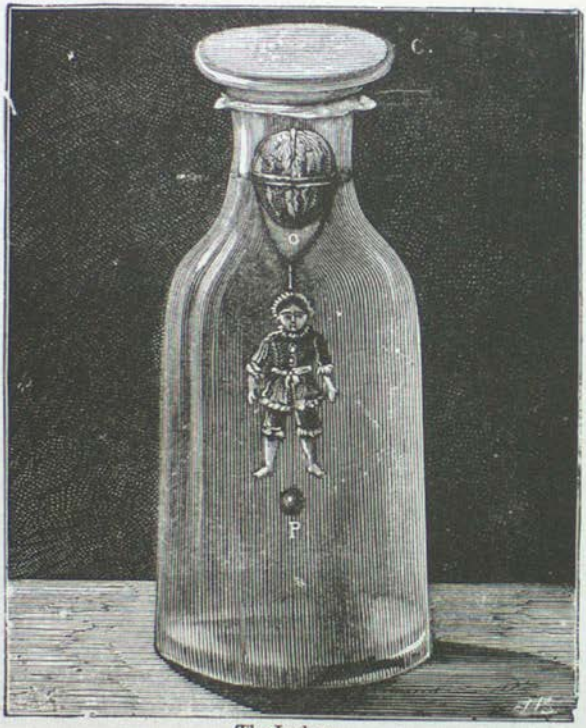


The Pump.

We have now seen that air is a gas, that it exercises pressure, that it possesses weight. We know it can be applied to many useful purposes, and that the air machines and inventions—such as the air-pump and the "Pneumatic Despatch"—are in daily use in our laboratories, our steam engines, our condensed milk manufactories, and in many other industries, and for our social benefit. Compressed air is a powerful motor for boring machinery in tunnels where steam cannot be used, even if water could be supplied, for smoke or fire would suffocate the workers. To air we owe our life and our happiness on earth.

Pneumatics, then, deals with the mechanical properties of elastic fluids represented by air. A gas is an elastic fluid, and differs very considerably from water ; for a gas will fill a large or small space with equal convenience, like

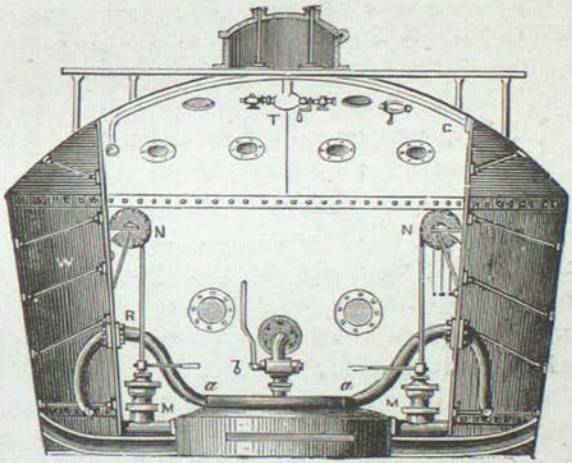
the genii which came out of the bottle and obligingly retired into it again to please the fisherman. We have seen that the pressure of the air is $14\frac{4}{5}$ lbs. per square inch at a temperature of 32°. It is not so easy to determine



The Lud.on.

the pressure of air at various times as that of water. We can always tell the pressure of a column of water when we find the height of the column, as it is the weight of so many cubic inches of the liquid. But the pressure of the atmosphere per square inch at any point is equal to the weight of a vertical column of air one inch square, reaching from that point to the limit of the atmosphere above it. Still the density is not the same at all points, so we

have to calculate. The average pressure at sea level is 14·7 per square inch, and sustains a column of mercury 1 square inch in thickness, 29·92, or say 30 inches high. These are the data upon which the barometer is based.



Diving-bell.

CHAPTER VI.—AERONAUTICS.

PRESSURE OF AIR IN BODIES—EARLY ATTEMPTS TO FLY IN THE AIR—DISCOVERY OF HYDROGEN—THE MONTGOLFIER BALLOONS—FIRST EXPERIMENTS IN PARIS—NOTED ASCENTS.

WE have now examined into the circumstances of air pressure; and in "Marvels of the Elements" we shall be told about the atmosphere and its constituents. We know that the air around us is composed principally of two gases, oxygen and nitrogen, with aqueous vapour and some carbonic acid. An enormous quantity of carbonic acid is produced every day, and were it not for the action of vegetation the amount produced would speedily set all animal life at rest. But our friends, the plants, decompose the carbonic acid by assimilating the carbon and setting free the oxygen which animals consume. Thus our atmosphere keeps its balance, so to speak. Nothing is lost in nature.

We have illustrated the pressure of the atmosphere by the Magdeburg hemispheres, and we know that the higher we ascend the pressure is lessened. The weight of the atmosphere is 15 lbs. to the square inch at sea level. This we have seen in the barometer. Now pressure is equal. Any body immersed in a liquid suffers pressure, and we remember Archimedes and the crown. It displaced a certain amount of water when

immersed. A body in air displaces it just the same. Therefore when any body is heavier than the air, it will fall just as a stone will fall in water. If it be of equal weight, it will remain balanced in the air, if lighter it will rise, till it attains a height where the weight of the atmosphere and its own are equal; there it will remain till the conditions are altered. Now we will readily understand why balloons float in the air, and why clouds ascend and descend in the atmosphere.

In this chapter we propose to consider the question of ballooning, and later the possibility of flying. We all have been anxious concerning the unfortunate balloonist who was lost in the Channel some years ago, so some details concerning the science generally, with the experiences of skilled aeronauts, will guide us in our selection of material. We will first give a history of the efforts made by the ancients to fly, and this ambition to soar above the earth has not yet died out.

From a very early period man appears to have been desirous to study the art of flying. The old myths of Dædalus and Icarus show us this, and it is not to be wondered at. When the graceful flight of birds is noticed, we feel envious almost that we cannot rise from the earth and sail away at our pleasure over land and sea. Any one who has watched the flight of the storks around and above Strasburg will feel desirous to emulate that long, swift-sailing flight without apparent motion of wing, and envy the accuracy with which the bird hits the point aimed at on the chimney, however small. It is little wonder that some heathens of old time looked upon birds as deities.

The earliest flying machine that we can trace is that invented by Archytas, of Tarentum, B.C. 400. The historian of the "Brazen Age" tells us how the geometrician, Archytas, made a wooden pigeon which was

able to sustain itself in the air for a few minutes, but it came down to the ground after a short time, notwithstanding the mysterious "aura spirit" with which it was supposed to be endowed. The capability of flying has for centuries been regarded as supernatural. Putting angels aside, demons are depicted with wings like bats' wings, while witches, etc., possessed the faculty of flying up chimneys upon broomsticks. We even read in childish lore of an old woman who "went up in a basket" (perhaps a balloon-car), and attained a most astonishing altitude—an elevation no less than "seventy times as high as the moon!"

But to descend to history. It is undoubtedly true that in the time of Nero Simon Magus attempted to fly from one house to another by means of some mechanical contrivance, and failing, killed himself. Roger Bacon, the "admirable doctor," to whom the invention of gunpowder is generally attributed, had distinct notions of flying by means of machines, and "hollow globes," and "liquid fire." But he did not succeed, nor did many successive attempts succeed any better in subsequent years. Bishop Wilkins treated of the art of flying, but most, if not all who discussed the subject appear to have been indebted to Roger Bacon for the idea.

When the nature and pressure of the atmosphere by Torricelli's experiments became better known, Father Lana, a Jesuit priest, constructed a flying machine or balloon of curious shape. He proposed to fix four copper globes, very thin, and about twenty feet in diameter, and to these he fastened a boat or car, looking very much like a basin. His idea was to empty his great copper globes, and that their buoyancy would then bear the weight of the traveller. But he overlooked or was ignorant of the effect of the atmospheric pressure, which would have speedily crushed the thin copper globes when empty.

Lana's suggestion was made in 1670, the barometer had been discovered in 1643.

There were some fairly successful experiments made in flying in 1678 and in 1709. The former attempt was made by Besmir, a locksmith of Sable, who raised himself by means of wings up to the top of a house by leaps, and then succeeded in passing from one house to another lower down by supporting himself in the air for a time. He started from an elevated position, and came down by degrees. Dante, a mathematician, also tried to fly, but without great success. He broke his thigh on one occasion. Laurence de Gusman claimed an invention for flying in 1709, and petitioned for a "patent," which was granted by the king's letter. The machine appears to have borne some resemblance to a bird.

It was not till 1782, however, that the true art of aerial navigation was discovered. The knowledge of hydrogen gas possessed by Cavendish in 1766 no doubt led up to it, and in the year following its discovery Professor Black, lecturing in Edinburgh, stated that it was much lighter than the atmosphere, and that any vessel filled with the gas would rise in the air. We now come to the invention of the BALLOON (so called from its shape being similar to a vessel used in the laboratory) by the Brothers Montgolfier.

Stephen and James Montgolfier were paper-makers, and carried on their business at Annonay, near Lyons, but it was partly by accident that the great discovery was made. They had no knowledge of the buoyancy of hydrogen gas. They took their idea of the balloon (inflated) from noticing an ascending column of smoke. It occurred to Stephen that if a paper bag were filled with smoke it would ascend into the air. A large bag was made and some paper burnt beneath it in a room. When the smoke had filled the bag it was released, and immediately

ascended to the ceiling. Here was the germ of the Montgolfier or heated air balloon. The experiment was repeated in the open air with even greater success, and a trial upon a larger scale was immediately determined upon. A story is related of Montgolfier when prosecuting



Montgolfier balloon.

his researches, that a widow whose husband had belonged to the printing firm with whom Montgolfier was then connected in business, saw the smoke issuing from the room in which the little balloon was being filled. She entered, and was astonished to see the difficulty experienced by the experimenter in filling the balloon. It swerved aside, and increased the trouble he had to keep

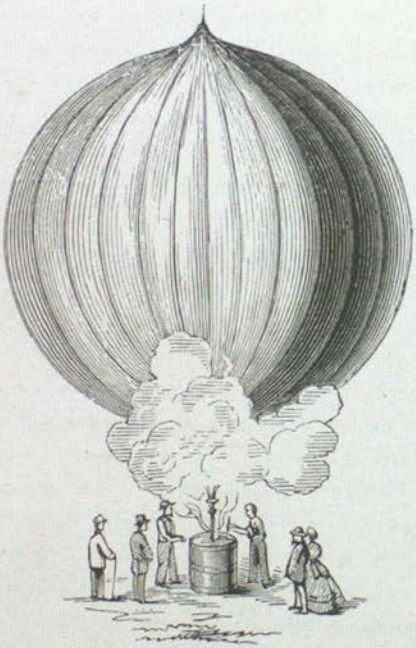
it above the chafing dish. Montgolfier was greatly troubled, and seeing his disappointment, the widow said, "Why don't you fasten the balloon to the chafing dish?" This had not occurred to the experimenter, and the idea was a valuable one. That was the secret of success.

The Montgolfier Brothers determined to exhibit their successful experiment, and accordingly on the 5th of June, 1783, a great concourse assembled to see the wonderful sight. A large canvas or linen balloon was made and suspended over a fire of chopped straw. The heated air quickly filled the balloon, which rose high in the air, and descended more than a mile away. This balloon contained 22,000 cubic feet of heated air, which is lighter than cold air, and of course rising carried the globe with it. As soon as the air began to cool the balloon ceased to rise, and as it got colder descended.

Here was the actual discovery of the science of Aerostatics. The intelligence of the success achieved soon spread from France to other countries. Paris, however, was in advance, and the Brothers Robert applied hydrogen gas to a balloon which was sent up from the Champ de Mars in August 1783. There was some trouble experienced in filling it, but when the balloon was at length released it realized all expectations by remaining in the air nearly an hour. When at length it fell it met with a worse fate than it deserved, for the ignorant and superstitious peasantry at once destroyed it. After this Montgolfier exhibited his experiment this time at Versailles in the presence of the Court. The first aerial travellers appeared on this occasion—viz., a sheep, a cock, and a duck, which were secured in the car. They all descended in safety, and this success encouraged M. Pilatre de Rozier to make an attempt in a "fire balloon." He went up first in a captive balloon, and at length he and a friend, the Marquis d'Arlandes, ascended from the Bois de

Boulogne. The trip was a decided success, and the possibility of navigating the air was fully demonstrated.

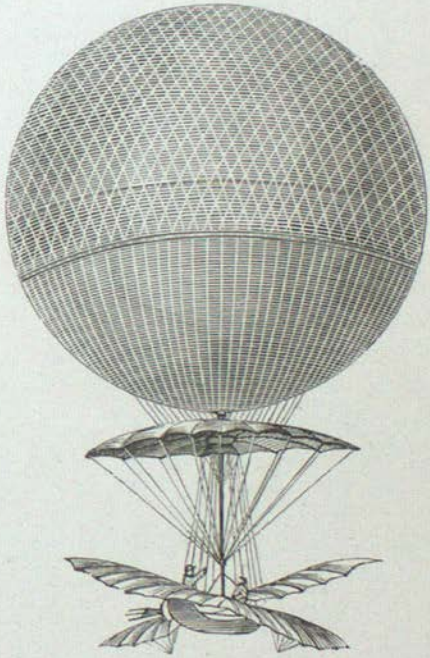
Soon after this,—viz., in December 1783,—an Italian Count, named Zambeccari, made an ascent in London, and came down safely at Petworth. MM. Charles and Robert ascended from Paris in December, and in February



MM. Charles' and Roberts' balloon.

a balloon crossed the English Channel. We must pass over some time and come to the ascents of Lunardi, which caused great excitement in London. His balloon was a very large one, and was inflated, or rather partially so, at the Artillery ground. Some delay occurred, and fearing a riot, M. Lunardi proposed to go up alone with the partially-filled balloon. A Mr. Biggin who had in-

tended to ascend was left behind, The Prince of Wales was present, and thousands of spectators. Lunardi cast off and ascended rapidly, causing great admiration from the whole metropolis. Judge and jury, sovereign and ministers, all turned out to gaze at the balloon ; a guilty prisoner was acquitted hurriedly, so that no time was lost



Blanchard's balloon.

in discussion, and one lady died of excitement. Lunardi was regarded as a hero, and made many other ascents. He died in 1806.

In those earlier days one or two fatal accidents happened. Count Zambeccari and a companion were in a balloon which caught fire, and both occupants of the car leaped from it as they were descending. The Count was killed

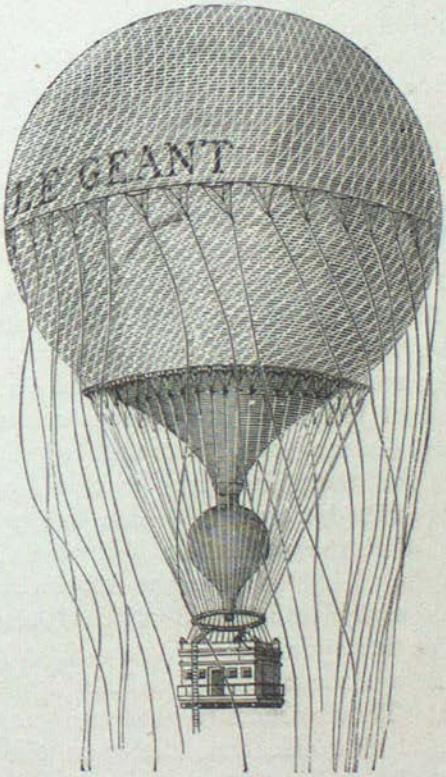
on the spot, and his companion was much injured. Pilatre de Rozier made an attempt to cross the channel to England in 1785; he had reached three thousand feet when the balloon caught fire, and the unfortunate traveller



The Nassau balloon.

was precipitated to the ground. His associate only survived him a few minutes. It is to the celebrated English aeronaut, Mr. Green, that the substitution of carburetted hydrogen or street gas for hydrogen is due, and since his ascent in 1821 no other means of inflation have been used. A great many quite successful and a few un-

successful ascents have been made for pleasure or profit. Mr. Green, in the *Nassau* balloon, passed over to Nassau, a distance of five hundred miles, in eighteen hours. This exploit was the cause of the name being bestowed upon



The "Giant" balloon of M. Nadar.

the balloon. The *Giant* of M. Nadar was exhibited in England, and it was an enormous one, being an hundred feet high, and nearly as wide in the widest part. But even this machine was outdone by the Godard "Montgolfier" balloon, which was one hundred and seventeen feet high,

and carried a stove. We give illustrations of these celebrated balloons, and will now pass on to the more scientific portion of the subject and the ascents of Mr. Glaisher and other aeronauts for the purpose of making meteorological observations, and the use of balloons for purposes of observation in war.

It appears that the first ascent for scientific investigation was made in the year 1803. The aeronauts were Messrs. Robertson and Lhoest. They ascended from Hamburg and came down at Hanover, and made meantime several experiments with reference to the electrical condition of the atmosphere, its influence upon a magnetic needle, and some experiments with regard to acoustics and heat. The report was presented to the St. Petersburg Academy, and contains the result of their interesting observations. The travellers ascertained that at the elevation to which they attained,—viz., 25,500 feet,—the temperature was on that July day fifty degrees colder, falling to 19·6°, while on the earth the thermometer had shown 68°. They ascertained that glass and wax did not become electric when rubbed, that the Voltaic battery lost much of its power, that the oscillation of a "dipping needle" increased as they mounted into the air, while sound was certainly less easily transmitted at that elevation, and struck them as less powerful in tone. The heat experiment was not a success, owing to the breaking of the thermometer. They wished to find the temperature of boiling water at that elevation, but when the experiment was about to be made Robertson accidentally plunged the instrument *into the fire* instead of into the water. So the question was not settled.

The effect upon the aeronauts was a sensation of sleepiness, and two birds died. The muscular powers of the voyagers also appear to have been much affected, and similar sensations may be experienced by travellers

on high mountains who find their breath very short and a disinclination to exertion oppress them.

MM. Biot and Gay-Lussac made a very interesting ascent in 1804. We will detail their experiences at some length, for the coolness displayed and the value of the observations made are remarkable in the history of scientific ballooning. They started at 10 o'clock a.m. on the 23rd of August, and when the balloon had carried them up to an altitude of 8,600 feet they commenced their experiments. They had some animals in the car with them, a bee amongst the number, and the insect was let go first. It flew away swiftly, not at all inconvenienced apparently. The sun was very hot at 56° Fahr. Their pulses were beating very fast, but no inconvenience was felt.

When 11,000 feet had been reached a linnet was permitted to go at large, but after a little time the bird returned to the balloon. It remained perched for a few minutes, and then dashed downwards at a tremendous pace. A pigeon was then liberated. It also appeared very uncertain, and wheeled around in circles for a time. At last it gained confidence and descended, and disappeared in the clouds beneath. They made other experiments, but descended without having obtained as accurate results as had been anticipated.

On the next occasion, however, every care was taken, and on the 15th of September the important ascent was made by Gay-Lussac alone. He fixed hanging ropes to the balloon with the view to check the rotating movements, and having provided himself with all necessary apparatus and two vacuum flasks to bring down some of the upper air, the young man started. The barometer marked 30·66°, the thermometer 82° (Fahr.). At an elevation of 12,680 feet Lussac perceived that the variation of the compass was the same as on land. Two

hundred feet higher up he ascertained that a key held in the magnetic direction repelled with the lower, and attracted with its upper extremity the north pole of a needle. This experiment was repeated with the same result at an elevation of 20,000 feet, which shows how the earth exercises its magnetic influence. The temperature of the air was found to decrease in proportion as the ascent up to 12,000 feet, where the reading was 47·3°. It then increased up to 14,000 feet by 6°, and then regularly diminished again as the balloon rose, till at the greatest elevation reached, 23,000 feet, there was a difference of 67° in the temperature on the earth, for at the maximum height attained the thermometer stood at 14·9°.

But the most important fact ascertained, and one which set many theories at rest, was the composition of the atmosphere in those high altitudes. We mentioned that Gay-Lussac took up two empty flasks from which the air had been taken. The vacuum was almost perfect. When the aeronaut had reached 21,460 feet he opened one flask, and it was quickly filled; he secured it carefully; and when at his highest point,—four miles and a half above the sea-level,—he opened the other flask. The barometer stood at 12·95 inches, and the cold was very great. The voyager felt benumbed, and experienced difficulty of breathing; his throat was parched and dry. So Lussac determined to return, he could go no higher. He dropped gently near Rouen, and soon reached Paris. As soon as possible the air in the flasks was submitted to very delicate tests, and to the satisfaction of the scientists engaged it was found to be in exactly the same proportions as that collected near the earth—two hundred and fifteen parts of oxygen to every thousand of atmospheric air.

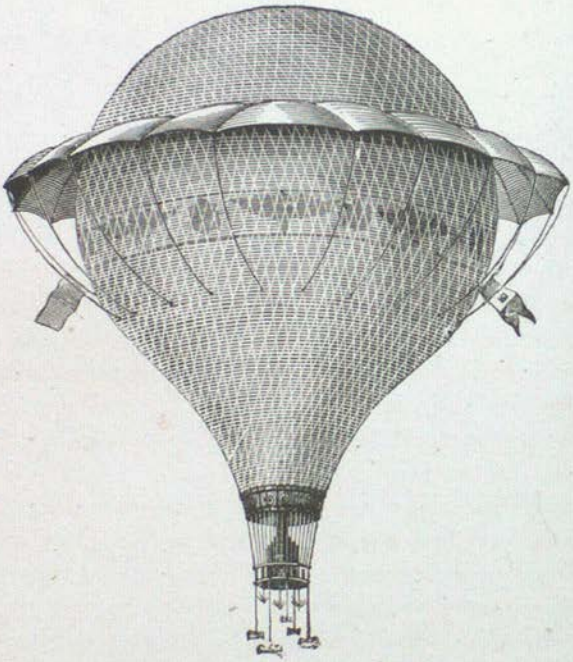
Messrs. Banal and Bixio, in 1850, also made some observations, and found the temperature very variable.

At 23,000 feet they found the thermometer at *minus* 38·2° Fahr., which was much below the cold experienced by Gay-Lussac. We may still conclude that the various currents of the atmosphere cause considerable variation, and that it is impossible to lay down any law respecting the degrees of heat and cold likely to be found at certain elevations. We quote Arago's observations upon this ascent :—

"This discovery" (the ice particles found in the air) "explains how these minute crystals may become the nucleus of large hailstones, for they may condense round them the aqueous vapour contained in the portion of the atmosphere where they exist. They go far to prove the truth of Mariotte's theory, according to which these crystals of ice suspended in the air are the cause of parahelia—or mock-suns and mock-moons. Moreover, the great extent of so cold a cloud explains very satisfactorily the sudden changes of temperature which occur in our climates."

M. Flammarion gives in his "Voyages" some very interesting and amusing particulars, as well as many valuable scientific observations. During one ascent he remarked that the shadow of the balloon was *white*, and at another time dark. When white the surface upon which it fell looked more luminous than any other part of the country! The phenomenon was an *anthelion*. The absolute silence impressed the voyager very much. He adds, "The silence was so oppressive that we cannot help asking ourselves are we still alive! We appear to appertain no longer to the world below." M. Flammarion's observations on the colour of what we term the sky are worth quoting—not because they are novel, but because they put so very clearly before us the appearance we call the "blue vault." He says,—speaking of the non-existence of the "celestial vault,"—"The air reflects the blue rays of the solar spectrum from every side. The white light of

the sun contains every colour, and the air allows all tints to pass through it except the blue. This causes us to suppose the atmosphere is blue. But the air has no such colour, and the tint in question is merely owing to the reflection of light. Planetary space is absolutely black;



The "Eagle" of M. Godard.

the higher we rise the thinner the layer of atmosphere that separates us from it, and the darker the sky appears."

Some beautiful effects may be witnessed at night from a balloon, and considering the few accidents there have been in proportion to the number of ascents, we do not wonder at balloon voyages being undertaken for mere pleasure. When science has to be advanced there can be

no objection made, for then experience goes hand-in-hand with caution. It is only the ignorant who are rash; the student of Nature learns to respect her, and to attend to her admonitions and warnings in time. The details of the ascents of famous aeronauts give us a great deal of pleasant and profitable reading. The phenomena of the sky and clouds, and of the heavens, are all studied with great advantage from a balloon, or "aerostat," as it is the fashion to call it. The grand phenomena of "Ulloa's circles," or *anthelia*, which represent the balloon in air, and surrounded by a kind of glory, or aureola, like those represented behind saintly heads, appear, as the name denotes, opposite to the sun.

The various experiments made to ascertain the intensity of sounds have resulted in the conclusion that they can be heard at great distances. For instance, the steam whistle is distinctly audible 10,000 feet up in the air, and human voices are heard at an altitude of 5,000 feet. A man's voice alone will penetrate more than 3,000 feet into the air; and at that elevation the croaking of frogs is quite distinguishable. This shows that sound ascends with ease, but it meets with great resistance in its downward course, for the aeronaut cannot make himself audible to a listener on the earth at a greater distance than 300 or 400 feet, though the latter can be distinctly heard at an elevation of 1,600 feet. The diminution of temperature noted by M. Flammarion is stated to be 1° Fahr. for every 345 feet on a fine day. On a cloudy day the mean decrease was 1° for every 354 feet of altitude. The temperature of clouds is higher than the air surrounding them, and the decrease is more rapid near the surface, less rapid as the balloon ascends. We may add that at high elevations the cork from a water-bottle will pop out as if from a champagne flask.

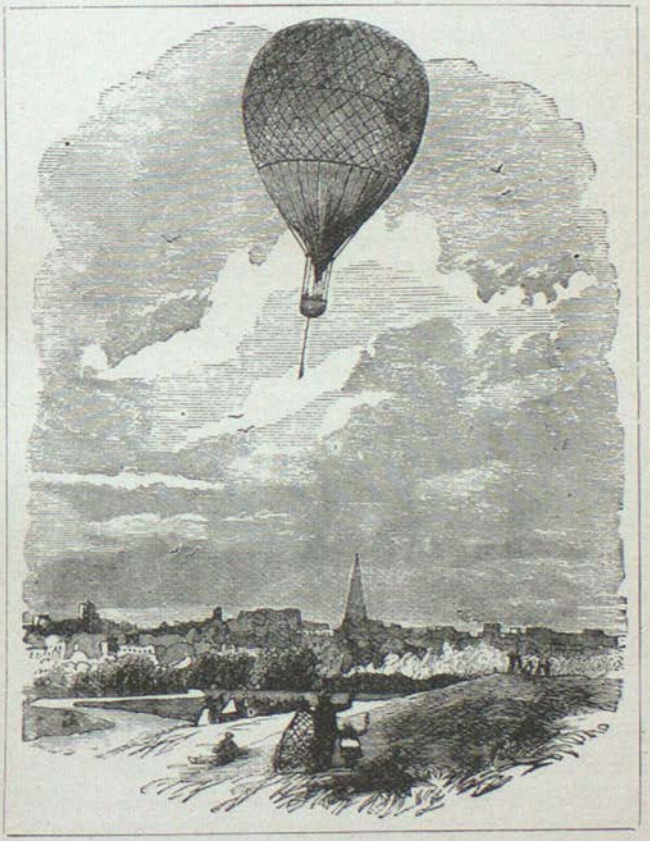
We have hitherto referred more to M. Flammarion and

other French aeronauts, but we must not be considered in any way oblivious of our countrymen, Messrs. Glaisher, Green, and Coxwell, nor of the American,—one of the most experienced of aerial voyagers,—Mr. Wise. The scientific observations made by the French voyagers confirmed generally Mr. Glaisher's experiments. This noted air-traveller made twenty-eight ascents in the cause of science, and his experiences related in "Travels in the Air," and in the "Reports" of the British Association, are both useful and entertaining. For "Sensational ballooning" one wishes to go no farther than his account of his experience with Mr. Coxwell, when (on the 5th of September, 1862) he attained the greatest elevation ever reached—viz., seven miles, or thirty-seven thousand feet.

We condense this exciting narrative for the benefit of those who have not seen it already.

The ascent was made from Wolverhampton. At 1.39 p.m., the balloon was four miles high, the temperature was 8°, and by the time the fifth mile had been reached the mercury was below zero, and up to this time observations had been made without discomfort, though Mr. Coxwell, having exerted himself as aeronaut, found some difficulty in breathing. About 2 o'clock, the balloon still ascending, Mr. Glaisher could not see the mercury in the thermometer, and Mr. Coxwell had just then ascended into the ring above the car to release the valve line which had become twisted. Mr. Glaisher was able to note the barometer, however, and found it marked 10 inches, and was rapidly decreasing. It fell to $9\frac{3}{4}$ inches, and this indicated an elevation of 29,000 feet! But the idea was to ascend as high as possible, so the upward direction was maintained. "Shortly afterwards," writes Mr. Glaisher, "I laid my arm upon the table possessed of its full vigour, and on being desirous of using it I found it powerless,—it must have lost power momentarily.

I tried to move the other arm, and found it powerless also. I then tried to shake myself, and succeeded in shaking my body. I seemed to have no limbs. I then



A descending balloon.

looked at the barometer, and whilst doing so my head fell on my left shoulder."

Mr. Glaisher subsequently quite lost consciousness, and "black darkness" came. While powerless he heard Mr. Coxwell speaking, and then the words, "Do try, now

do." Then sight slowly returned, and rousing himself, Mr. Glaisher said, "I have been insensible." Mr. Coxwell replied, "You have, and I, too, very nearly." Mr. Coxwell's hands were black, and his companion had to pour brandy upon them. Mr. Coxwell's situation was a perilous one. He had lost the use of his hands, which were frozen, and had to hang by his arms to the ring and drop into the car. He then perceived his friend was insensible, and found insensibility coming on himself. There was only one course to pursue—to pull the valve line and let the gas escape, so as to descend. But his hands were powerless! As a last resource he gripped the line with his teeth, and bending down his head, after many attempts succeeded in opening the valve and letting the gas escape. The descent was easily made, and accomplished in safety.

Some pigeons were taken up on this occasion, and were set free at different altitudes. The first, at three miles, "dropped as a piece of paper"; the second, at four miles, "flew vigorously round and round, apparently taking a dip each time"; a third, a little later, "fell like a stone." On descending a fourth was thrown out at four miles, and after flying in a circle, "alighted on the top of the balloon." Of the remaining pair one was dead when the ground was gained, and the other recovered.

The observations noted are too numerous to be included here. Some, we have seen, were confirmed by subsequent aeronauts, and as we have mentioned them in former pages we need not repeat them. The results differed very much under different conditions, and it is almost impossible to decide upon any law. The direction of the wind in the higher and lower regions sometimes differed, sometimes was the same, and so on. The "Reports" of the British Association (1862-1866) will furnish full particulars of all Mr. Glaisher's experiments.

We have scarcely space left to mention the parachutes

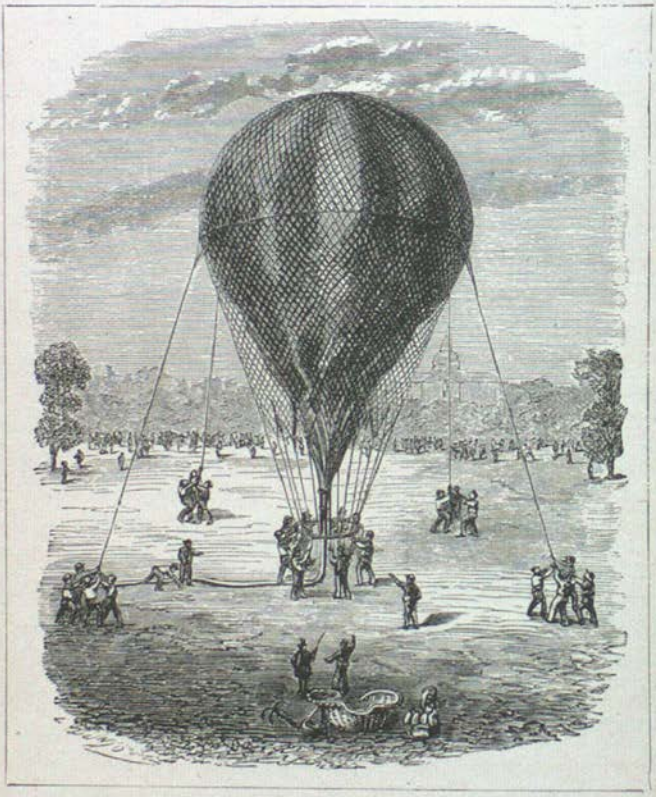
or umbrella-like balloons which have occasionally been used. Its invention is traced to very early times; but Gamerin was the first who descended in a parachute, in 1797, and continued to do so in safety on many subsequent occasions. The parachute was suspended to a balloon, and at a certain elevation the voyager let go and came down in safety. He ascended once from London, and let go when 8,000 feet up. The parachute did not expand as usual, and fell at a tremendous rate. At length it opened out, and the occupier of the car came down forcibly, it is true, but safely. The form of the parachute is not unlike an umbrella opened, with cords attaching the car to the extremities of the "ribs," the top of the basket car being fastened to the "stick" of the umbrella.

Mr. Robert Cocking invented a novel kind of parachute, but when he attempted to descend by it from Mr. Green's balloon it collapsed, and the unfortunate voyager was dashed to pieces. His remains were found near Lee, in Kent. Mr. Hampton did better on Garneron's principle, and made several descents in safety and without injury.

The problem of flying in the air has attracted the notice of the Aeronautical Society, established in 1873, but so far without leading to practical results, though many daring and ingenious suggestions have been put forth in the "Reports."

It is not within our province to do more than refer to the uses of the balloon for scientific purposes, but we may mention the services it was employed upon during the French war, 1870-71. The investment of Paris by the German army necessitated aerial communication, for no other means were available. Balloon manufactories were established, and a great number were made, and carried millions of letters to the provinces. Carrier pigeons were used to carry the return messages to the city, and photography was applied to bring the correspondence into

the smallest legible compass. The many adventures of the aeronauts are within the recollection of all. A few of the balloons never reappeared ; some were carried into Norway, and beyond the French frontier in other directions.



Filling a balloon.

The average capacity of these balloons was 70,000 cubic feet.

Of course it will be understood how balloons are enabled to navigate the air. The envelope being partly filled with coal-gas-heated air and hydrogen is much lighter than the

surrounding atmosphere, and rises to a height according as the density of the air strata diminishes. The density is less as we ascend, and the buoyant force also is lessened in proportion. So when the weight of the balloon and its occupants is the same as the power of buoyancy, it will come to a stand, and go no higher. It can also be understood that as the pressure of the outside becomes less, the expansive force of the gas within becomes greater. We know that gas is very compressible, and yet a little gas will fill a large space. Therefore, as the balloon rises, it retains its rounded form, and appears full even at great altitudes; but if the upper part were quite filled before it left the ground, the balloon would inevitably burst at a certain elevation when the external pressure of the air would be removed, unless an escape were provided. This escape is arranged for by a valve at the top of the balloon, and the lower part above the car is also left open very often, so that the gas can escape of itself. When a rapid descent is necessary, the top valve is opened by means of a rope, and the balloon sinks by its own weight. Mr. Glaisher advises for great ascensions a balloon of a capacity of 90,000 cubic feet, and only filled one-third of that capacity with gas. Six hundred pounds of ballast should be taken.

A very small quantity of ballast thrown away will make a great difference; a handful will raise the balloon many feet, and a chicken bone cast out occasions a rise of thirty yards. The ballast is carried in small bags, and consists of dry sand, which speedily dissipates in the air as it falls. By throwing out ballast the aeronaut can ascend to a great height—in fact, as high as he can go, the limit apparently for human existence being about seven miles, when cold and rarefied air will speedily put an end to human life.

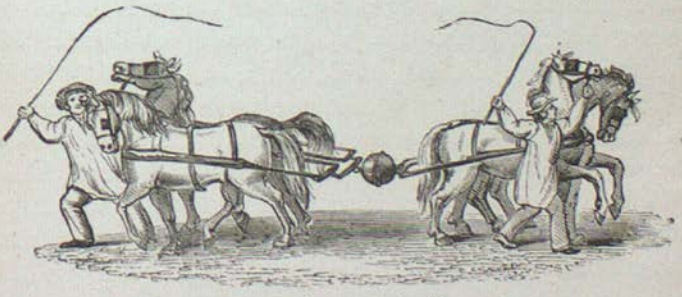
It is a curious fact, that however rapidly the balloon

may be travelling through the air, the occupants are not sensible of the motion. This, in part, arises from the impossibility of comparing it with other objects. We pass nothing stationary which would indicate the pace at which we travel. But the absence of oscillation is also remarkable; even a glass of water may be filled brim-full, and to such a level that the water is above the rim of the glass, and yet not a drop will fall. This experiment was made by M. Flammarion. When the aeronaut has ascended some distance the earth loses its flat appearance, and appears as concave as the firmament above. Guide ropes are usually attached to balloons, and as they rest upon the ground they relieve the balloon of the amount of weight the length trailing would cause. They thus act as a kind of substitute for ballast as the balloon is descending. Most of the danger of aerial travelling lies in the descent; and though in fine weather the aeronaut can calculate to a nicety where he will descend on a windy day, he must cast a grapnel, which catches with an ugly jerk, and the balloon bounds and strains at her moorings.

Although many attempts have been made to guide balloons through the air, no successful apparatus has ever been completed for use. Paddles, sails, fans, and screws have all been tried, but have failed to achieve the desired end. Whether man will ever be able to fly we cannot of course say. In the present advancing state of science it may not be impossible ere long to supply human beings with an apparatus worked by electricity, perhaps, which will enable them to mount into the air and sustain themselves. But even the bird cannot always fly without previous momentum. A rook will run before it rises, and many other birds have to "get up steam," as it were, before they can soar in the atmosphere. Eagles and such heavy birds find it very difficult to rise from the

ground. We know that vultures when gorged cannot move at all, or certainly cannot fly away; and eagles take up their positions on high rocks, so that they may launch down on their prey, and avoid the difficulty of rising from the ground. They swoop down with tremendous momentum and carry off their booty, but often lose their lives from the initial difficulty of soaring immediately. We fear man's weight will militate against his ever becoming a flying animal. When we obtain a knowledge of the atmospheric currents we shall no doubt be able to navigate our balloons; but until then—and the information is as yet very limited, and the currents themselves very variable—we must be content to rise and fall in the air, and travel at the will of the wind in the upper regions of the atmosphere.

We shall have more to say upon this subject in a subsequent book about some novel modes of locomotion in water and air. We will now glance at water and its uses.



The Resistance of the Air.

CHAPTER VII.—WATER.

ABOUT WATER—HYDROSTATICS AND HYDRAULICS—LAW OF ARCHIMEDES—THE BRAMAH PRESS—THE SYPHON—SPECIFIC GRAVITY.

AT present we will pass from Air to Water, from Pneumatics to Hydrostatics and Hydraulics. We must remember that Hydrostatics and Hydraulics are very different. The former treats of the weight and pressure of liquids when they are at rest, the latter treats of them in motion. We will now speak of the properties of Liquids, of which Water may be taken as the most familiar example.

We have already seen that Matter exists in the form of Solids, Liquids, and Gases, and of course Water is one form of Matter. It occupies a certain space, is slightly compressible; it possesses weight, and exercises force when in motion. It is a fluid, but also a liquid. There are fluids not liquid, such as air or steam, to take equally familiar examples. These are elastic fluids and compressible, while water is inelastic, and termed incompressible.

We may state that water is composed of oxygen and hydrogen, and proportions of eight of the former to one of the latter by weight; in volume the hydrogen is as two to one.

From these facts, as regards water, we learn that volume and weight are very different things,—that equal volumes of various things may have different weights, and

that volume (or bulk) by no means indicates weight. Equal volumes of feathers and sand will weigh very differently.

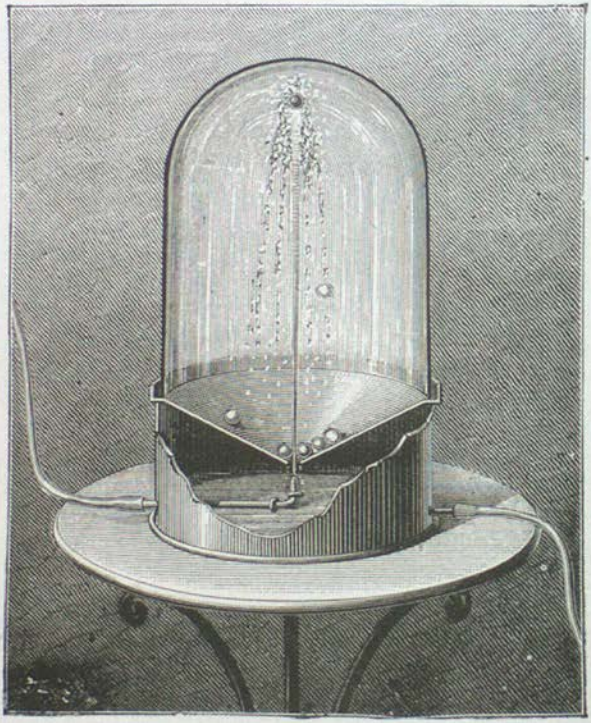
[The old "catch" question of the "difference in weight between a pound of lead and a pound of feathers" here comes to the mind. The answer generally given is that "feathers make the heavier 'pound,' because they are weighed by avoirdupois, and lead by troy weight." This is an error. They are both weighed in the same way, and pound for pound, are the same *weight*, though different in *volume*.

Fluids in equilibrium have all their particles at the same distance from the centre of the earth, and although within small distances liquids appear perfectly level (in a direct line), they must, as the sea does, conform to the shape of the earth, though in small levels the space is too limited to admit of any deviation from the plane at right angle to the direction of gravity.

Liquids always fall to a perfectly level surface, and water will seek to find its original level, whether it be in one side of a bent tube, in a watering pot and its spout, or as a fountain. The surface of the water will be on the same level in the arms of a bent tube, and the fountain will rise to a height corresponding with the elevation of the parent spring whence it issues. The waterworks companies first pump the water to a high reservoir, and then it rises equally high in our high-level cisterns.

As an example of the force of water, a pretty little experiment may be easily tried, and, as many of our readers have seen in a shop in the Strand in London, it always is attractive. A good-sized glass shade should be procured and placed over a water tap and basin, as per the illustration over-leaf. Within the glass put a number of balls of cork or other light material. Let a stop-cock, with a small aperture, be fixed upon the tube leading into the glass. Another tube to carry away the water should, of course, be provided, but it may be used over again.

When the tap is properly fixed, if the pressure of the water be sufficient, it will rush out with some force, and catching the balls as they fall to the bottom of the glass shade bear them up as a juggler would throw oranges from hand to hand. If coloured balls be used the effect

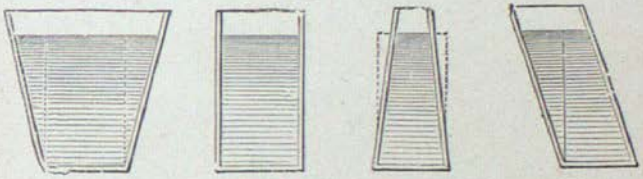


Water jet and balls.

may be enhanced, and much variety imparted to the experiment, which is very easy to make.

Water exercises an enormous pressure, but the pressure does not depend upon the amount of water in the vessel. It depends upon the vessel's height, and the dimensions of the base. This has been proved by filling vessels

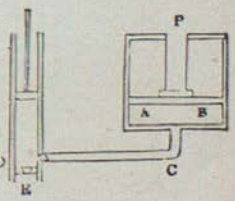
whose bases and heights are equal, but whose shapes are different, each holding a different quantity of water. The pressure at the bottom of each vessel is the same, and depends upon the depth of the water. If we subject a portion of the liquid surface to certain force, this pressure will be dispersed equally in all directions, and from an acquaint-



Pressure of water.

ance with this fact the Hydraulic Press was brought into notice. If a vessel with a horizontal bottom be filled with water to a depth of one foot, every square foot will sustain a pressure of 62·37 lbs., and each square inch of 0·433 lbs.

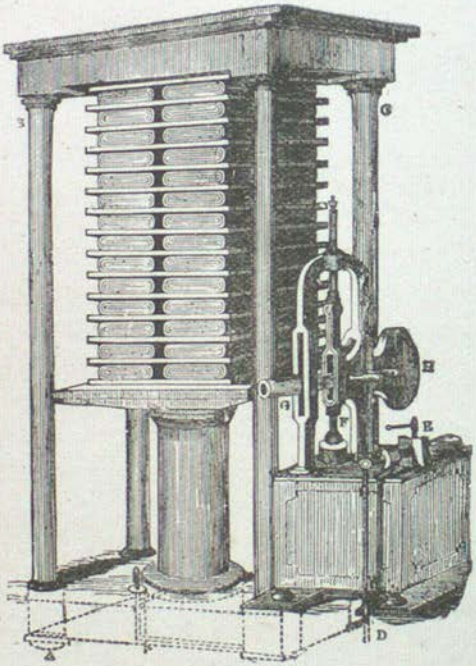
We will now explain the principle of this WATER PRESS. In the small diagram, the letters AB represent the bottom of a cylinder which has a piston fitted in it (P). Into the opposite side a pipe is let in, which leads from a force-pump, D, which is fitted with a valve, E, opening upwards. When the piston in D is pulled up water enters through the valve; when the piston is forced down the valve shuts, and the water rushes into the chamber, AB. The pressure pushes up the large piston with a force multiplied as many times as the area of the small piston is contained in the large one. So if the large one be ten times as great as the small one, and the latter be forced down with a 10 lb. pressure, the pressure on the large one will be 100 lbs., and so on.



Water Press.

The accompanying illustration shows the form of the Hydraulic or Bramah Press. A B C D is a strong frame, F the force-pump worked by means of a lever fixed at G, and H is the counterpoise. E is the stop-cock to admit the water.

The principles of hydrostatics will be easily explained.



Bramah Press.

The Lectures of M. Aimé Schuster, Professor and Librarian at Metz, have taught us in a very simple manner the principle of Archimedes, in which it is laid down that "a body immersed in a liquid loses a portion of its weight equal to the weight of the liquid displaced by it." We take a body of as irregular form as we please; a stone, for example. A thread is attached to the stone, and it is then placed in a glass of water full up

to the brim. The water overflows; a volume of the liquid equal to that of the stone runs over. The glass thus partially emptied is then dried, and placed on the scale of a balance, beneath which we suspend the stone; equilibrium is established by placing some pieces of lead in the other scale. We then take a vase full of water, into which we plunge the stone suspended from the scale, supporting the vase by means of bricks. The equilibrium is now broken; to re-establish it, it is necessary to fill up with water the glass placed on the scale; that is to say, we put back in the glass the weight of a volume of water precisely equal to that of the stone.

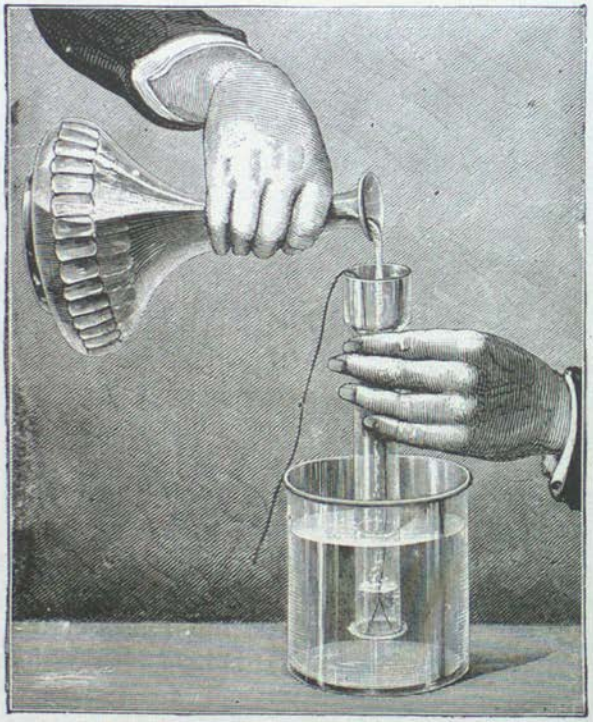
If it is desired to investigate the principles relating to connected vessels, springs of water, artesian wells, etc., two funnels, connected by means of an india-rubber tube of certain length, will serve for the demonstration; and by placing the first funnel at a higher level, and pouring in water abundantly, we shall see that it overflows from the second.

A disc of cardboard and a lamp-glass will be all that is required to show the upward pressure of liquids. I apply to the opening of the lamp-glass a round piece of cardboard, which I hold in place by means of a string; the tube thus closed I plunge into a vessel filled with water. The piece of cardboard is held by the pressure of the water upwards. To separate it from the opening it suffices to pour some water into the tube up to the level of the water outside. The outer pressure exercised on the disc, as well as the pressure beneath, is now equal to the weight of a body of water having for its base the surface of the opening of the tube, its depth being the distance from the cardboard to the level of the water.

Syringes, pumps, etc., are the effects of atmospheric pressure. Balloons rise in the air by means of the pressure of gas; a balloon being a body plunged in gas, is con-

sequently submitted to the same laws as a body plunged in water.

Boats float because of the pressure of liquid, and water spurts from a fountain for the same reason. I recollect



Demonstration of the upward pressure of liquids.

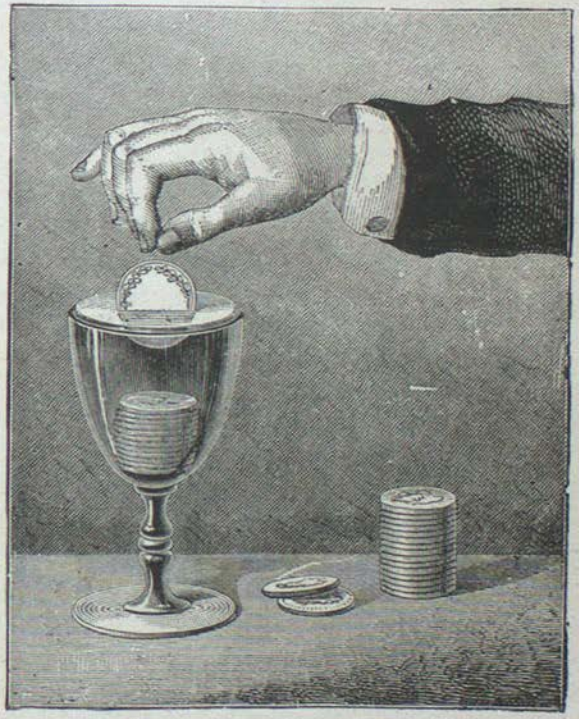
having read a very useful application of the principles of fluid pressure.

A horse was laden with two tubs for carrying a supply of water, and in the bottom of the tubs a valve was fixed. When the horse entered the stream the tubs were partly immersed ; the water then exercised its upward pressure, the valve opened, and the tubs slowly filled. When they

were nearly full the horse turned round and came out of the water ; the pressure had ceased.

Thus the action of the water first opened the valve, and then closed it.

The particular phenomena observable in the water level

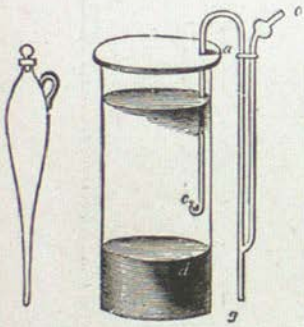


Experiment on the convexity of a meniscus.

in narrow spaces, as of a fine glass tube, or the level of two adjoining waves, capillary phenomena, etc., do not need any special appliance for demonstration, and it is the same with the convexity or concavity of meniscuses.*

* The curved surface of a column of liquid is termed a "meniscus," from the Greek word *meniskos*, meaning "a little lens."

The foregoing cut represents a pretty experiment in connection with these phenomena. I take a glass, which I fill up to the brim, taking care that the meniscus be concave, and near it I place a pile of pennies. I then ask my young friends how many pennies can be thrown into the glass without the water overflowing. Everyone who is not familiar with the experiment will answer that it will only be possible to put in one or two, whereas it is possible to put in a considerable number, even ten or twelve. As the pennies are carefully and slowly dropped in, the surface of the liquid will be seen to become more and more convex, and one is surprised to what an extent this convexity increases before the water overflows.

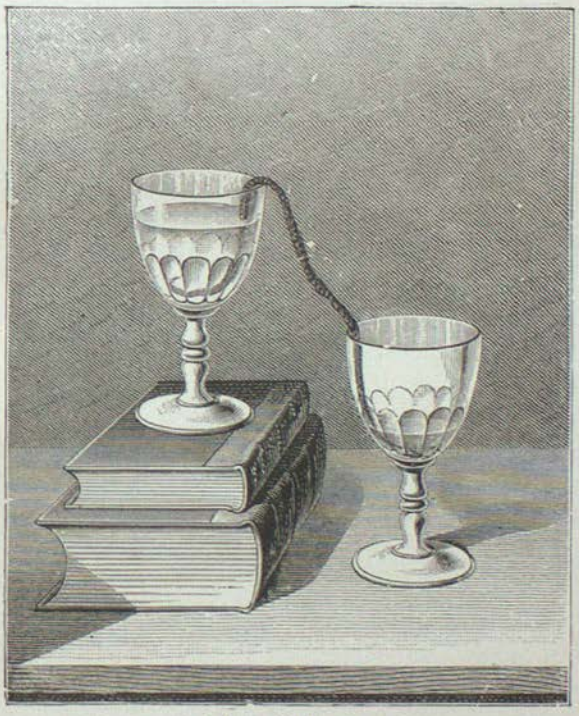


The Syphon

The common *syphon* may be mentioned here. It consists of a bent tube with limbs of unequal length. We give an illustration of the syphon. The shorter leg being put into the mixture, the air is exhausted from the tube at *o*, the aperture at *g* being closed with the finger. When the finger is removed the liquid will run out. If the water were equally high in both legs the pressure of the atmosphere would hold the fluid in equilibrium, but one leg being longer, the column of water in it preponderates, and as it falls, the pressure on the water in the vessel keeps up the supply.

Apropos of the syphon, we may mention a very simple application of the principle. Cut off a strip of cloth, and arrange it so that one end shall remain in a glass of water while the other hangs down, as in the illustration. In a short time the water from the upper glass will have passed through the cloth-fibres to the lower one.

This attribute of porous substances is called *capillarity*, and shows itself by *capillary attraction* in very fine pores or tubes. The same phenomenon is exhibited in blotting paper, sugar, wood, sand, and lamp-wicks, all of which give familiar instances of capillarity. The cook makes use of

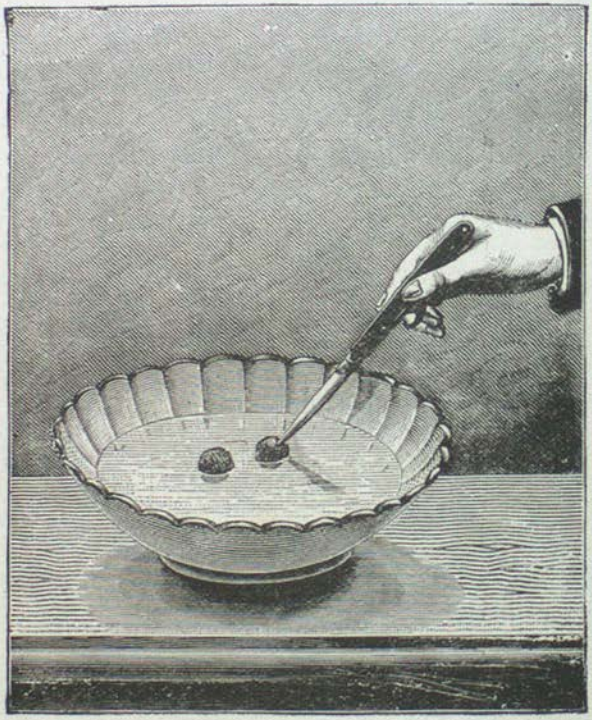


An improvised syphon.

this property by using thin paper to absorb grease from the surface of soups.

Capillarity (already referred to) is the term used to define capillary force, and is derived from the word *capillus*, a hair; and so very small bore tubes are called capillary tubes. We know that when we plunge a glass tube into

water the liquid will rise up in it, and the narrower the tube the higher the water will go ; moreover, the water inside will be higher than at the outside. This is in accordance with a well-known law of adhesion, which induces concave or convex surfaces in the liquids in the tubes, according

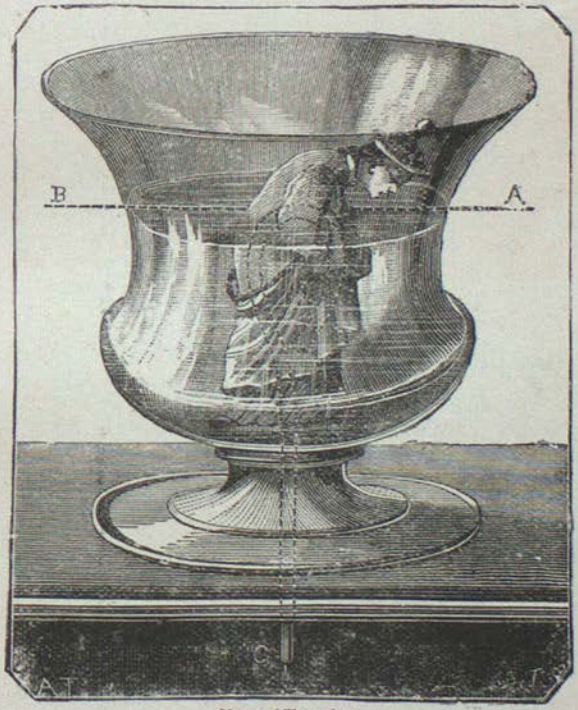


Molecular attraction.

as the tube is wetted with the liquid or not. For instance, water, as we have said, will be higher in the tube and concave in form ; but mercury will be depressed below the outside level, and convex, because mercury will not adhere to glass. When the force of cohesion to the sides of the tube is more than twice as great as the adhesion of the

particles of the liquid, it will rise up the sides, and if the forces be reversed, the rounded appearance will follow. This accounts for the convex appearance, or "meniscus," in the column of mercury in a barometer.

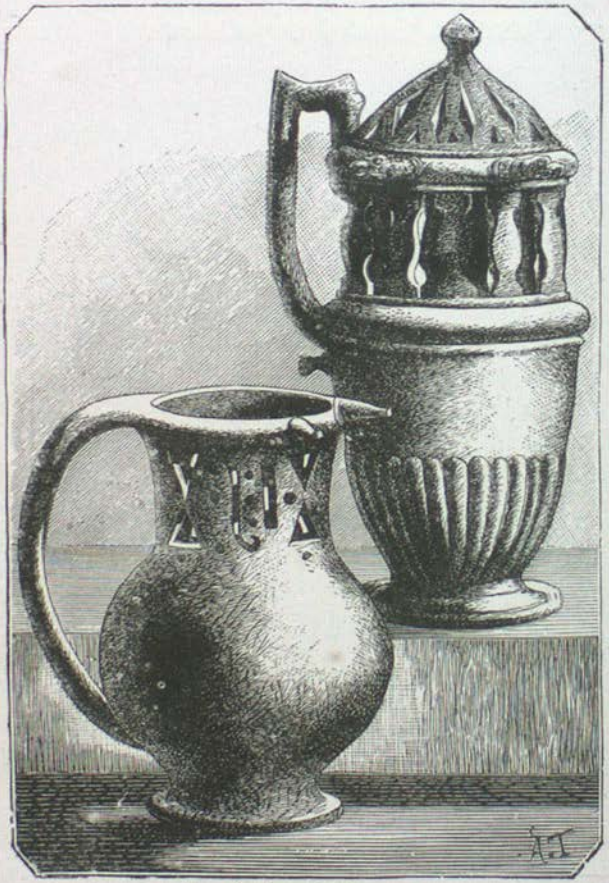
Amongst the complicated experiments to demonstrate



Vase of Tantalus.

molecular attraction, the following is very simple and very pretty:—Take two small balls of cork, and having placed them in a basin half-filled with water, let them come close to each other. When they have approached within a certain distance they will rush together. If you fix one of them on the blade of your pen-knife, it will attract the other as a magnet, so that you can lead it round the basin. But

if the balls of cork are covered with grease they will *repel* each other, which fact is accounted for by the form of the *menisques*, which are convex or concave, according as they



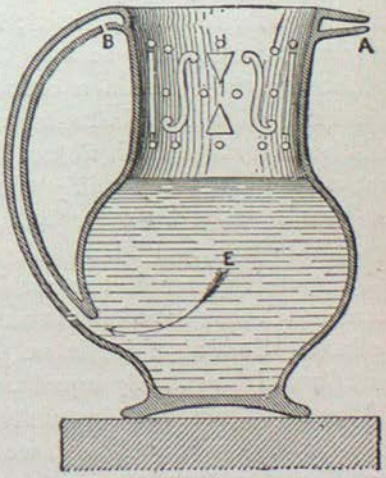
Deception jugs of old pattern.

are moistened, or preserved from action of the water by the grease.

This attribute is of great use in the animal and vegetable kingdoms. The rising of the sap is one instance of the latter.

Experience in hydrostatics can be easily applied to amusing little experiments. For instance, as regards the syphon, we may make an image of *Tantalus* as per illustration. A wooden figure may be cut in a stooping posture, and placed in the centre of a wide vase, as if about to drink. If water be poured slowly into the vase it will never rise to the mouth of the figure, and the unhappy *Tantalus* will remain in expectancy. This result is obtained by the aid of a syphon hidden in the figure, the shorter limb of which is in the chest. The longer limb descends through a hole in the table, and carries off the water. These vases are called *vases of Tantalus.*

The principle of the syphon may also be adapted to our domestic filters. Charcoal, as we know, makes an excellent filter, and if we have a block of charcoal in one of those filters,—now so common,—we can fix a tube into it, and clear any water we may require. It sometimes (in the country) happens that drinking-water may become turgid, and in such a case the syphon filter will be found useful.



Section of jug.

The old "deception" jugs have often puzzled people. We give an illustration of one, and also a sketch of the "deceptive" portion. This deception is very well managed, and will create much amusement if a jug can be procured; they were fashionable in the eighteenth century and previously. A cursory inspection of these curious utensils will lead one to vote them utterly useless. They

are, however, very quaint, and if not exactly useful are ornamental. They are so constructed, that if an inexperienced person wish to pour out the wine or water contained in them, the liquid will run out through the holes cut in the jug.

To use them with safety it is necessary to put the spout, A, in one's mouth, and close the opening, B, with the finger, and then by drawing in the breath, cause the water to mount to the lips by the tube which runs around the jug. The specimens herein delineated have been copied from some now existent in the museum of the Sèvres china manufactory.

The *Buoyancy of Water* is a very interesting subject, and a great deal may be written respecting it. The swimmer will tell us that it is easier to float in salt water than in fresh. He knows by experience *how difficult it is to sink* in the sea ; and yet hundreds of people are drowned in the water, which, if they permitted it to exercise its power of buoyancy, would help to save life.

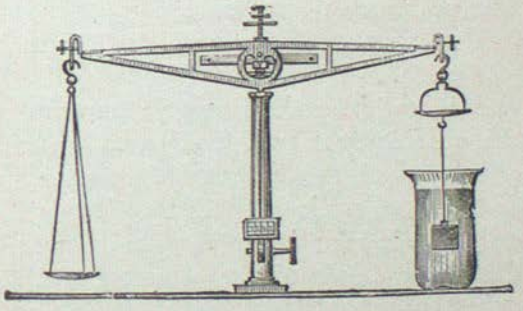
The sea-water holds a considerable quantity of salt in solution, and this adds to its resistance, or floating power. It is heavier than fresh water, and the Dead Sea is so salt that a man cannot possibly sink in it. This means that the man's body, bulk for bulk, is much lighter than the water of the Dead Sea. A man will sink in fresh, or ordinary salt water if the air in his lungs be exhausted, because without the air he is much heavier than water, bulk for bulk. So if anything is weighed in water, it apparently loses in weight exactly equal to its own bulk of water.

Water is the means by which *Specific Gravity* of liquids or solids is found, and by it we can determine the relative densities of matter in proportion. Air is the standard for gases and vapours. Let us examine this, and see what is meant by SPECIFIC GRAVITY.

We have already mentioned the difference existing

between two equal volumes of different substances, and their weight, which proves that they may contain a different number of atoms in the same space. We also know, from the principle of Archimedes, that *if a body be immersed in a fluid, a portion of its weight will be sustained by the fluid equal to the weight of the fluid displaced.*

[This theorem is easily proved by filling a bucket with water, and moving it about in water, when it will be easy to lift; and likewise the human body may be easily sustained in water by a finger under the chin.]

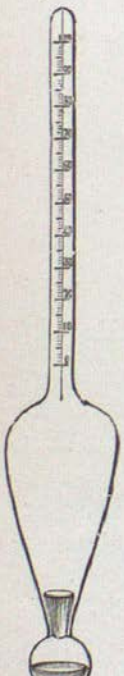


Weighing metal in water.

The manner in which Archimedes discovered the displacement of liquids is well known, but is always interesting. King Hiero, of Syracuse, ordered a crown of gold to be made, and when it had been completed and delivered to His Majesty, he had his doubts about the honesty of the goldsmith, and called to Archimedes to tell him whether or not the crown was of gold, pure and simple. Archimedes was puzzled, and went home deep in thought. Still considering the problem he went to the bath, and ... his abstraction filled it to the brim. Stepping in he spilt a considerable quantity of water, and at once the idea struck him that any body put into water would displace its own bulk of the liquid. He did not wait to dress, but ran half-naked to the palace, crying out, "Eureka, Eureka! I

have found it, I have found it!" What had he found?—He had solved the problem.

He got a lump of gold the same weight as the crown, and immersed it in water. He found it weighed nineteen times as much as its own bulk of water. But when he immersed the king's crown he found it displaced more water than the pure gold had done, and consequently it had been adulterated by a lighter metal. He assumed that the alloy was silver, and by immersing lumps of silver and gold of equal weight with the crown, and weighing the water that overflowed from each dip, he was able to tell the king how far he had been cheated by the goldsmith.



Hydrometer.

It is by this method now that we can ascertain the specific gravity of bodies. One cubic inch of water weighs about half an ounce (or to be exact, 252½ grains). Take a piece of lead and weigh it in air; it weighs, say, eleven ounces. Then weigh it in a vase of water, and it will be only ten ounces in weight. So lead is eleven times heavier than water, or eleven ounces of lead occupy the same space as one ounce of water.

[The heavier a fluid is, or the greater its density, the greater will be the weight it will support. Therefore we can ascertain the purity or otherwise of certain liquids by using hydrometers, etc., which will float higher or lower in different liquids, and being gauged at the standard of purity, we can ascertain (for instance) how much water is in the milk when supplied from the dairy.]

But to return to SPECIFIC GRAVITY, which means the "Comparative density of any substance relatively to water," or as Professor Huxley says, "The weight of a

volume of any liquid or solid in proportion to the weight of the same volume of water, at a known temperature and pressure."

Water, therefore, is taken as the unit; so anything whose equal volume under the same circumstances is twice as heavy as the water, is declared to have its specific gravity 2; if three-and-a-half times it is 3·5, and so on. We append a few examples; so we see that things which possess a higher specific gravity than water sink, which comes to the same thing as saying they are heavier than water, and *vice versâ*.

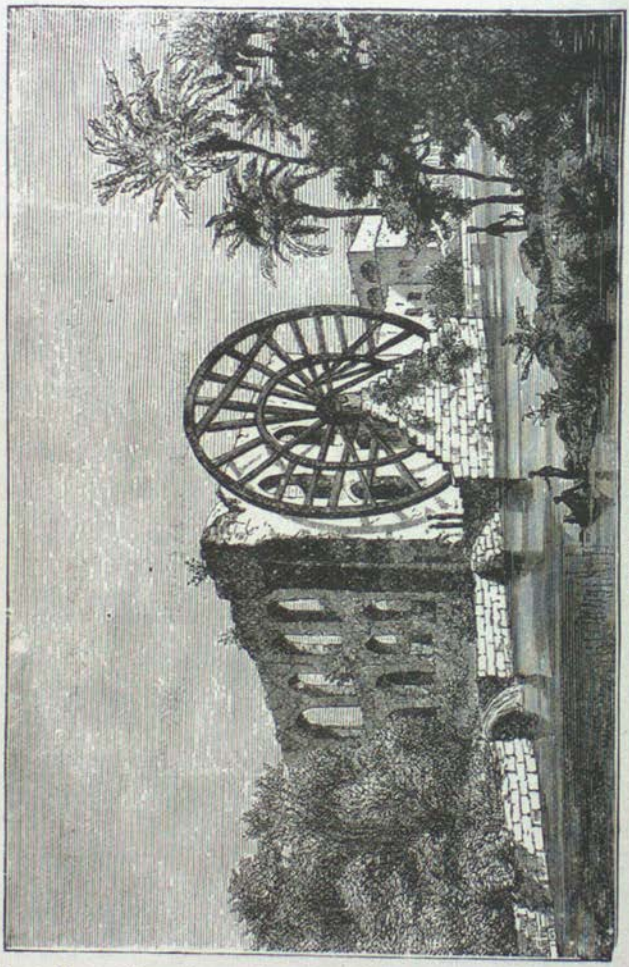
To find the specific gravity of any solid body proceed as above, in the experiment of the lead. By weighing the substance in and out of water we find the weight of the water displaced; that is, the first weight less the second. Divide the weight in air by the remainder, and we shall find the specific gravity of the substance.

The following is a table of specific gravities of some very different substances, taking water as the unit.

Substance.	Specific Gravity.	Substance.	Specific Gravity.	Substance.	Specific Gravity.
Platinum .	21·5	Iron . .	7·79	Water .	1·000
Gold . .	19·5	Tin . .	7·29	Sea Water .	1·026
Mercury .	13·59	Granite .	2·62	Rain Water	1·001
Lead . .	11·45	Oak Wood .	0·77	Ice . .	·916
Silver . .	10·50	Cork . .	0·24	Ether . .	0·723
Copper .	8·96	Milk . .	1·032	Alcohol .	0·793

But we have by no means exhausted the uses of water. Hydrodynamics, which is the alternative term for hydraulics, includes the consideration of many forms of water-wheels, most of which, as mill-wheels, are under-shot, or over-shot accordingly as the water passes horizontally over the floats, or acts beneath them. These wheels are used in relation to the fall of water. If there is plenty of water and a slight fall, the under-shot wheel is used. If there is a good

fall less water will suffice, as the weight and momentum of the falling liquid upon the paddles will turn the wheel. Here is the Persian water-wheel, used for irrigation. The

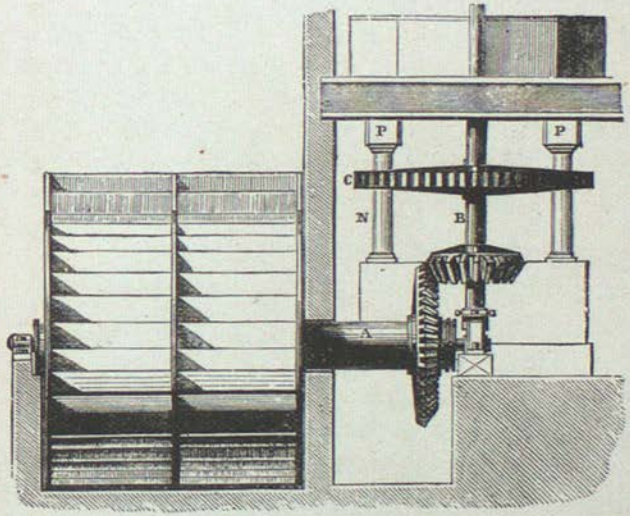


Irrigation wheel in Egypt.

Archimedian Screw, called after its inventor, was one of the earliest modes of raising water. It consists of a cylinder somewhat inclined, and a tube bent like a screw within it.

By turning the handle of the screw the water is drawn up and flows out from the top.

The Water Ram is a machine used for raising water to a great height by means of the momentum of falling water.



Over-shot wheel of mill.

The Hydraulic Lift is familiar to us all, as it acts in our hotels, and we need only mention these appliances here; full descriptions will be found in Cyclopædias.

WONDERS OF THE HEAVENS.

PREFACE.

AMONG the marvels of astronomy, not the least astonishing, when rightly considered, are the practical bearings of the science upon our daily life, and upon the commerce of the world. The understanding of the most elementary conditions of our life depends upon the knowledge we have gained of the motions of the sun and stars, and of their relation to our own earth. Our natural ideas about our position in the universe of existing things are in reality upside-down, or totally erroneous. Untaught humanity imagines itself to live upon a nearly flat surface, extending equally in every direction, and supposes that the sun, moon, and stars pass across the heavens and sink down, to reappear in their place of rising by some mysterious process. Long ages of close observation were needed before men, absorbed in such preconceived notions, could boldly launch out into such a grand conception as that of Copernicus, who realised that the sun is the central body around which the planets revolve, and that the apparent daily motion of the heavens is not real, but is due to the rotation of the earth round its own axis. The discovery of Kepler's laws (given on page 7) followed, and enabled our own immortal Newton to imagine and to prove his

great law of universal gravitation. It is quite true that Newton, while still a young man—only twenty-three years of age—was led to the supposition of universal gravitation by seeing an apple fall from a tree at his native place, Woolsthorpe, in Lincolnshire. It occurred to Newton that, inasmuch as the force by which the apple fell to the ground is not diminished at the greatest distance from the earth's centre to which we can reach,—and if he had lived in ballooning days, he would have been confirmed by the universal fall of balloons to the ground when no longer inflated, however high they may have risen,—the same force might extend as far as the moon, and be the means of retaining her in her orbit, thus travelling in a curve instead of going on in a straight line. Thus, if the moon was kept in her orbit by the attractive force of the earth, instead of travelling away, it was equally likely that the planets were similarly kept in their orbits by the attractive force of the sun. Kepler's law of the motions of the planets being known to Newton, it was necessary to prove that the motions so laid down were in agreement with such a force of gravitation ; and a theory of the intensity of the force must be imagined in order to test the idea. Newton hit upon the grand idea that the force of gravity or attraction, by which the planets were retained in their orbits, varied inversely as the square of their distances from the sun ; that is, that taking a certain distance as the standard, at double the distance, the intensity of the force would be one quarter as great. The first thing was to compare the actual force exhibited by falling bodies at the earth's surface with that shown by the motion of the moon ; and in this calculation it was necessary to have a correct measurement of the length of a degree of latitude. Newton unfortunately had not access to a nearly correct measurement which had just been made, and, taking the measurement at sixty miles for a degree, he found that

the two things he wished to compare would not agree. Newton was disappointed in his hopes, and turned to other lines of investigation, and for many years the great discovery slumbered.

Twenty years later Newton was able to use a still more correct determination of the length of a degree, and at last set to work upon a calculation, which bade fair to prove the correctness of his theory. It is said that when he perceived that the calculation was coming out right, the great discoverer became so excited and nervous, that he could not complete it, but was obliged to entrust it to a friend. When all was proved, after a further delay of some years, Newton gave to the world the incomparable "Principia," which at once based astronomy upon the securest mathematical principles. Will it be believed that Newton never received a penny for this magnificent effort of his intellect? So it is with the greatest work in most cases. It is either too early or too great to be rewarded.

By the sound observations of astronomy, aided by the belief that nature is uniform in her operations, and that any apparent inconsistency is due to imperfection in our knowledge, it is possible to foretell to the minute the positions of the planets for years to come, to calculate eclipses for vast periods in the future, to realise the relative positions of the earth and moon to the sun for great spaces of time, to calculate the paths of comets when they appear, and in many cases the time of their reappearance, to reckon with the greatest accuracy the length of the year, and, above all, perhaps, in interest to the commercial world, to fix the relative positions of the stars and planets at any given hour for years to come, and the time and height of the tides all over the world. Not only can this be done, but it is actually and regularly done, and is the foundation of all sound seamanship. In the *Nautical Almanac* these things are actually fixed with exactitude for four years in

advance, and the seaman has at his disposal the best means of knowing his position and progress, wherever he may be in any quarter of the world, at any time of day or night. Instead of haphazard guessing and many mistakes and wrecks, the navigator knows he can trust to his chart of the heavens and his almanac better even than he can trust to his geographical chart : the heavens have never been known to deceive him, while many a wreck has been due to mistakes or imperfections in geographical charts. If astronomical knowledge and its results were suddenly abolished, commerce across the seas would be in great part abolished, and the reckoning of time, involving the complex working of our railway system and the whole arrangements of business, would be done away ; the world's effective power would be reduced to one-tenth or one-twentieth of what it is. All these advantages of astronomy are the result of studies which some think theoretical, but which are truly in the highest degree practical and beneficial, nay, essential to mankind.

Surely this survey should give us a new interest in the labours of astronomers, sitting up through nights of cold, watching and accurately recording the positions of the stars, and laboriously making calculations from them in the day-time, in order that time and tide, which wait for no man, may be calculated and utilised by and for every man. And this feeling we venture to suggest, in addition to the natural emotions of every thinking person, who surveys the heavens with renewed wonder every time he gazes at the wonderful procession of stars, which from night to night partially expresses the unutterable glories of the Creator of them all.

MARVELS OF ASTRONOMY.

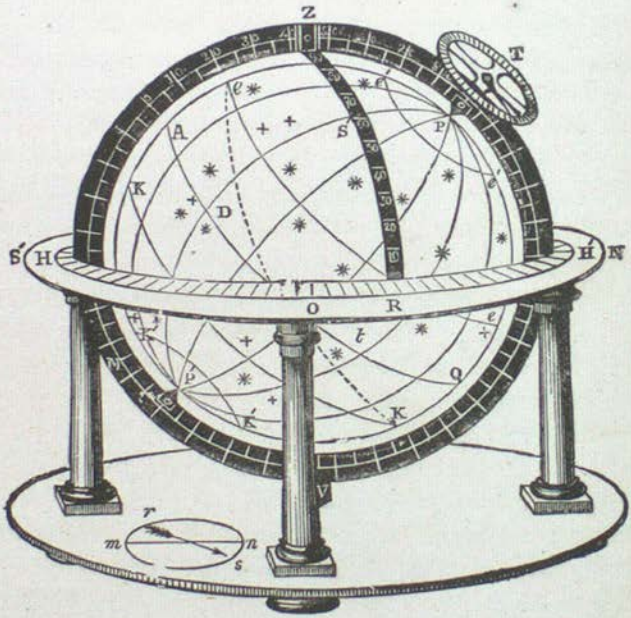
CHAPTER I.

INTRODUCTORY — HISTORY OF ASTRONOMY — NOMENCLATURE.

ASTRONOMY is the science which treats of the heavenly bodies and the laws which govern them. The term is derived from two Greek words, *astron*, a star, and *nomos*, a law. It may be included in the study of Physics, for the laws of motion and equilibrium, gravity, etc., all have much to do with the arrangements and positions of the stars. The space in which they are set is infinite, and known as the "Firmament," or "Heaven." The number of the heavenly bodies must therefore be infinite also. We can see a few stars, comparatively speaking, and there must be numbers whose light has never yet reached the earth. When we calmly reason upon the immeasurable distances and the awful rapidity of motion, with the masses of matter thus in movement, we are constrained to acknowledge that all our boasted knowledge is as nothing in the wondrous dispensations of Him "who telleth the number of the stars, and calleth them all by their names."

Astronomy, no more than any other of the physical

sciences, cannot stand by itself. We have seen how heat, light, electricity, etc., are all, in a manner, inter-dependent. So astronomy is dependent upon mathematics, particularly geometry and trigonometry, for the wondrous problems to be solved. But in the following sketch we do not propose to plunge the reader in the slough of calculations. We only desire to put plainly before him the great pheno-



Celestial globe.

mena of nature with regard to the heavens, and the glorious orbs which so thickly stud the space above us. We need not detail the laborious calculations by which philosophers have arrived at certain discoveries. We may refer to the results and explain general principles, thereby indicating the road by which the student may arrive at the more difficult bypaths in the fields of scientific discovery.

The history of astronomy is nearly as old as the world itself, or rather as old as the human race. From the earliest ages we can picture men gazing upon the "spangled heavens," and the wandering tribes of the desert were always very careful observers of the paths of the stars. To the nomads of the East the planetary system served as compass and clock, calendar and barometer.

We shall find, therefore, that many observations of the heavenly bodies were made by the ancients, and have descended to more advanced generations, and this leads us to remark that the science of astronomy can be studied without any very special or costly apparatus. In other branches of science numerous instruments are indispensable before we can reveal to ourselves the desired results. In astronomy, a telescope—even a good field glass, such as possessed by any household, will reveal many interesting facts. We may, by means of more expensive instruments, and by the aid of large telescopes particularly, enjoy the sight of the moon and planets. But even with the naked eye a great variety of phenomena may be observed. With a celestial globe in our hands upon a fine starry night, we can easily find out the position of the constellations, and trace their forms in the firmament.

It is to the Chaldeans, Indians, Chinese, and Egyptians, that our knowledge of astronomy is primarily due. They did much to facilitate the observation of the stars; they named the planets, grouped the stars, and marked the sun's track in the sky. *Astrology* was cultivated in very remote ages. The Jews practised it; and the astrologers of subsequent periods played very important parts in divining the future of individuals, and casting their *horoscopes*. Many of these so-called predictions came true, "because," as was remarked by Pascal, "as misfortunes are common they" (the astrologers) "are often right," as they foretold misfortune oftener than good fortune. Still the

fact remains that occasionally a very startling prediction was made, and proved true; such, for instance, as the laying waste of Germany by Gustavus Adolphus, which was foretold by Tycho Brahé after his consideration of a certain comet, and the date of the king's death was also correctly prophesied. Astrology, therefore, held a very considerable influence over the human race during the Middle Ages.

We can only give a very brief historical summary of the science. We know that the destinies of individuals and nations were at a very early period attributed to the influence of the stars. We read that "the stars in their courses fought against Sisera," and many expressions surviving to the present time serve to remind us that the stars were at one time paramount in men's minds. Thus we have the phrases—"unlucky star," "born under a lucky star," "mark my stars," "moonstruck," etc. Even the common term "consider"—to take counsel of the stars—is thus accounted for, and many men have a habit of looking up to the ceiling of a room or to the sky when thinking deeply—con-sidering with the stars. "Contemplate" is another term signifying the same thing; for *templum*, a temple, was formerly a space marked upon the sky in imaginary lines, and traced on the ground in accordance with the supposed diagram. Thus temple became a place for heavenly "contemplation," and by an easy transition to a place of worship. In our old poets' writings we have many allusions to the influences of the stars.

"Now glowed the firmament
With living sapphires; Hesperus, that led
The starry host, rode brightest, till the moon,
Riding in clouded majesty, at length
Apparent queen, unveiled her peerless light,
And o'er the dark her silver mantle threw."—MILTON.

Although from Thales, who lived B.C. 610, the real science of astronomy may be allowed to date, there can be no doubt that the ancients were acquainted with many phenomena. The Chaldeans were, doubtless, the first to place on record the rising and setting of the celestial bodies and eclipses, and used the water-clock (clepsydra). A list of eclipses from 2234 B.C. is stated to have been found at Babylon by Alexander the Great. The Chaldeans also divided the ecliptic into twelve equal parts, and the day and night into twenty-four hours. The Chinese, again, have recorded astronomical phenomena as far back as 2857 B.C.; and the Egyptians also were well versed in the science, although no records of much importance remain to us, unless the zodiac signs were their invention.

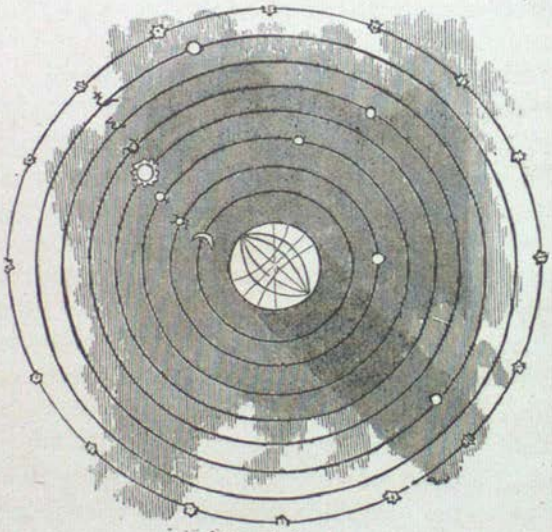
Thales predicted the eclipse of the sun B.C. 610. Aristarchus and Eratosthenes also made important observations. Hipparchus (160-125 B.C.) discovered the precession of the equinoxes, calculated eclipses, determined the length of the year, etc., etc.

Ptolemy, of Alexandria, A.D. 130-150, was the founder of a theory called the Ptolemaic System, which recognized the earth as the centre of all—the sun, moon, stars, etc., all revolving in very complicated courses around it, as figured in the diagram herewith. Even though his theory turned out to be untenable, he paved the way for his successors in other ways, and left a valuable collection of observations on record. In this volume, called the "Almagest," he reviewed the state of the science, and gave a catalogue of stars, as well as a description of the heavens. He discovered the lunar evection.

After his time astronomy, though it was not neglected, appeared to droop, and it is at a comparatively late period that we again open the records—viz., in 1543, the year in which Copernicus died. This philosopher, who was born in 1473, promulgated the true theory of the solar

system. He placed the sun in the centre of the planets, and by this he explained their motion around the sun, though they appeared to be carried round the earth. The book in which he explained his theory, "De Revolutionibus Orbium Celestium," was not finished till a day or two before he died.

The justly celebrated Tycho Brahé was the most important of the successors of Copernicus, but he opposed the Copernican theory, while other able philosophers agreed



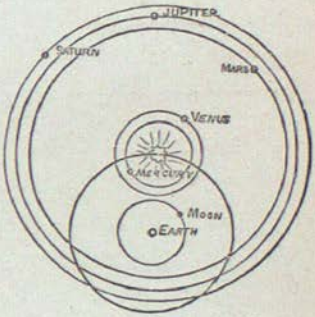
Ptolemaic System.

with it. Brahé was a Dane; he died in 1601. He adopted the theory that the sun and moon revolved around the earth, while the (other) planets moved around the sun. This theory did not gain much credence, but he, again, though he could not defeat Copernicus, and though he was wrong in his assumption, made many important investigations. After him came Kepler, whose observations upon the planet Mars cleared away many complications, and he laid down three laws, which are as follows :—

1. Every planet describes an elliptic orbit about the sun, which occupies one focus of each such ellipse.

2. If a line be drawn from the sun, continually, to any planet, this line will sweep over equal areas in equal times.

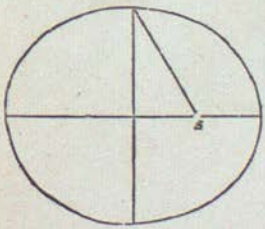
3. The squares of the periodic times of the planets are proportional to the cubes of their mean distances from the sun.



Copernican System.

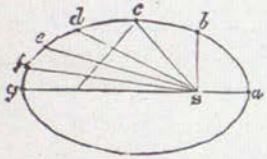
Kepler also remarked that gravity was a power existing between all bodies, and reasoned upon the tides being caused by the attraction of the moon for the waters.

It was about this time—viz., the beginning of the seventeenth century—that the telescope was invented, and logarithms came into use. The actual discoverer of this now almost perfected instrument is uncertain. Borelli, who wrote in the seventeenth century, ascribes the discovery to Zachariah Jansen and Hans Lippersheim, spectacle makers of Middleburg. Baptista Porta, also a spectacle maker, has had the credit of discovering the magnifying power of the lens, and, so far, the originator of the telescope.

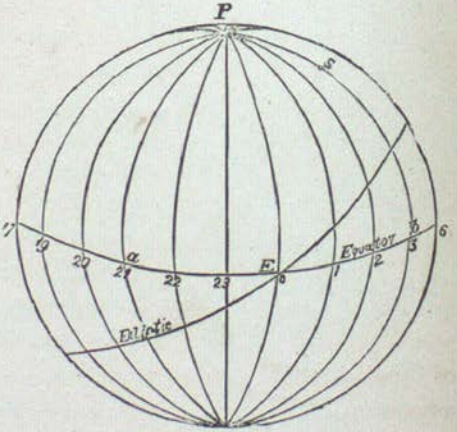

Ellipse.

But whoever invented it, the telescope did not penetrate into southern Europe till 1608-9. Galileo then made inquiries concerning the new instruments and Kepler made some propositions for their construction. But Harriot had used the instrument, so far back as 1611 or 1612, and had observed spots upon the sun's disc. Galileo, in 1610, had also made observations with the telescope,

and discovered the satellites of Jupiter. He thereby confirmed the Copernican theory;* and when Newton promulgated his immortal discovery of gravitation, after Picard's researches, the relations of the sun and planets became more evident. His researches were published in the *Principia*, and then one-half the scientific world began to question the principle of gravitation, which was supported by Newton and his adherents. Subsequently the researches of Lagrange and Laplace, Adams and Leverrier, Sir J. Herschel, etc., brought astronomy into prominence more and more; and the innumerable stars, indicated as new planets, have been discovered. The spectroscope, which gives us the analyses of the sun and other heavenly bodies, has, in the able hands of living astronomers, revealed to us elements existing in the vapours and composition of the sun, etc. Stars are now known to be suns, some bearing a great resemblance to our sun, others differing materially. The nebulæ have been analysed, and found to be stars, or gas, burning in space —hydrogen and nitrogen being the chief constituentsof this glowing matter. Instruments for astronomical obser-



Radii Vectores.

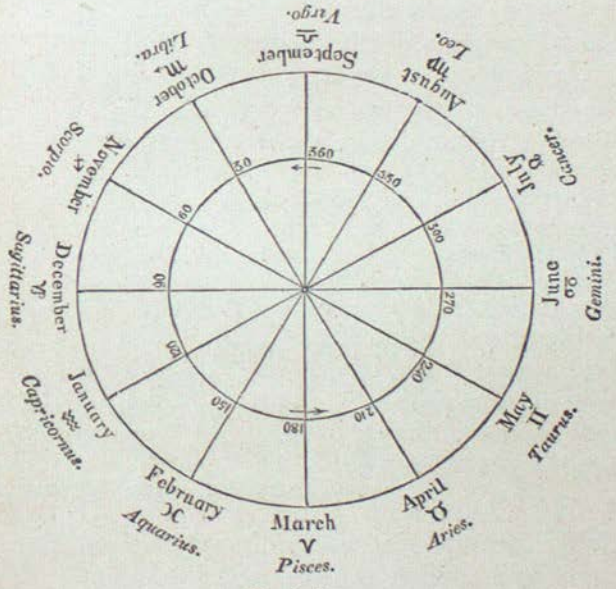


Ecliptic and Equator.

* He was obliged to recant before the Inquisition, and to repudiate his researches. He was released on the condition of observing silence upon the theory he had supported, but was again obliged to recant.

vation have now been brought to a pitch of perfection scarcely ever dreamed of, and month by month discoveries are made and recorded, while calculations as to certain combinations can be made with almost miraculous accuracy. The transit of Venus, the approaches of comets, eclipses, and the movements of stars, are now known accurately, and commented upon long before the event can take place.

We will close this chapter by giving a brief explanation



The Zodiac

of the various definitions most usually employed in astronomy.

1. The *Axis* of the earth is an *imaginary* line passing through the centre (north and south); the *poles* are the extremities of this line.

2. The *Equator* is an imaginary circle passing round the globe, dividing it into northern and southern hemispheres. The *equinoctial* is the plane of the former circle extended

to the heavens, and when the sun appears in that line the days and nights are of equal duration—twelve hours each

3. The *Ecliptic* is the sun's path through the heavens —though, of course, the sun does not actually move, and therefore the track, or supposed circle, is really the earth's motion observable from the sun. When the moon is near this circle eclipses happen. The ecliptic cuts the equinoctial at an angle of about 23°. One half is to the north and the other to the south of the equinoctial.

4. The *Zodiac* is a girdle extending 8° on each side of the ecliptic, in which space of 16° the planets move. The zodiac is divided into twelve parts of 30° each, called the "Signs." These names are as under written :—

NORTHERN SIGNS.

Spring.	*Summer.*
Aries, the Ram, March.	Cancer, the Crab, June.
Taurus, the Bull, April.	Leo, the Lion, July.
Gemini, the Twins, May.	Virgo, the Virgin, August.

SOUTHERN SIGNS.

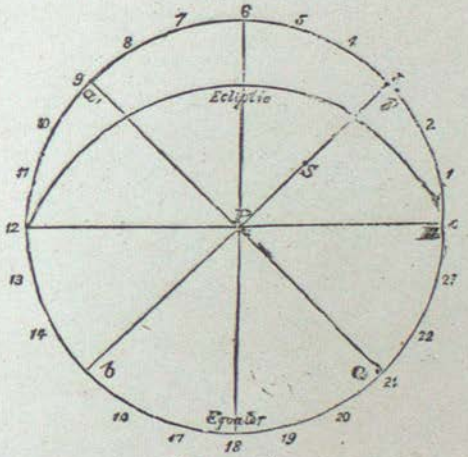
Autumn.	*Winter.*
Libra, the Balance, September.	Capricornus, the Goat, December.
Scorpio, the Scorpion, October.	Aquarius, the Waterbearer, January.
Sagittarius, the Archer, November.	Pisces, the Fishes, February.

5. *Colures* are two circles dividing the ecliptic into four equal parts, and making the seasons.

6. The *Horizon* is the boundary line of our vision, and is called the sensible (apparent) horizon. The true horizon is the circle—as on a globe—dividing the heavens into two hemispheres. The sensible horizon is enlarged according as the eye is elevated above the ground. A man six feet high can see a distance of three miles when standing on a plain. We can always find the distance visible when we know the height at which we stand, or inversely, we can tell the height of an object if we know the distance.

We have only to increase the height *one half in feet*, and extract the square root for the distance in miles. On giving the distance in miles reverse the operation.

For instance, for the man six feet high, as supposed, add three feet, being half his height ; that makes nine feet. The square root (or number multiplied by itself to give nine) is three, which is the number of miles the man can see on a plain. Or, again, suppose we can see a tower on the level, and we know we are twelve miles away from it. The square of twelve is one hundred and forty-

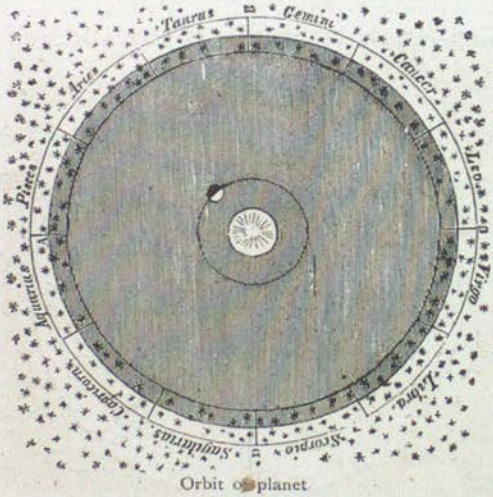


Right ascension.

four feet, one-third of that is forty-eight feet, which represents the half of the original height added to the whole tower in feet ; so the whole tower is ninety-six feet high. Reversing, as in the former case, we can prove this by taking the tower at ninety-six feet high and trying to find the distance we can see from its summit = 96 + 48 = 144 ; the square root of 144 = 12, the distance required.

7. The *Nadir* and the *Zenith* are the poles of the horizon. The zenith is exactly overhead, the nadir exactly under foot. Circles drawn through these points are azimuth circles.

8. *Meridians* are circles passing through the poles at right angles to the equinoctial. Every place is supposed to have a meridian, but only twenty-four are upon the globe, and they represent the sun's, or the planets', "movements" every hour—15° being one hour, 360° being twenty-four hours (*see* page 11). One quarter of a degree equals one minute of time. Parallels of latitude are familiar circles parallel to the equator. Latitude in astronomy is



Orbit of planet

the distance from the ecliptic at a right angle north or south. This will be explained as we proceed.

9. *Declination* is the distance of the heavenly bodies from the equinoctial measured as a meridian.

The *Tropics* indicate the limits of the sun's declination.

10. *Disc* is the term applied to the apparently flat surface of a planet, such as the moon, for instance.

11. The *Orbit* is the path described by a planet revolving round the sun. The plane of the orbit is an imaginary surface cutting through the centre of the sun and the planet, and extending to the stars. The diagram

shows the plane of the earth's orbit. The circle, A B C D (page 12), is the ecliptic. The inclination of an orbit is the plane of the orbit with reference to the plane of the earth ; and, supposing the shaded part of the illustration to be water, a hoop held *inclined towards the earth*, with one half in and the other half out of the water, will describe the planetary orbit.

12. *Nodes* are the opposite points of a planet where its orbit cuts the ecliptic or the earth's orbit.



Conjunction of Venus and Saturn.

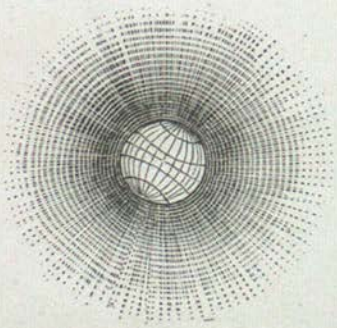
13. *Apogee* is the point of a planet's orbit farthest from the earth. Perigee is the nearest point.

14. The terms Culmination, Conjunction, and Opposition require no special explanation. But planets are in conjunction with each other when in the same sign and degree. A planet with the sun between it and the earth is in conjunction with the sun. With the earth between it and the sun it is in opposition.

15. Latitude and longitude upon a celestial globe are

known respectively as "Declination" and "Right Ascension."

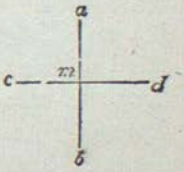
16. The Radius Vector is a line drawn from a planet to the sun, wherever the planet may be (*see* page 8).



CHAPTER II.—ANGLES AND MEASUREMENT OF ANGLES.

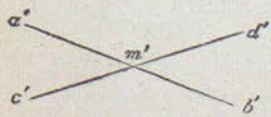
THE QUADRANT—TRANSIT INSTRUMENT—CLOCKS—STELLAR TIME—SOLAR TIME—"MEAN" TIME.

WE must say a few words respecting the various instruments and aids to astronomical observation before proceeding, for astronomy requires very accurate calculations; and though we do not propose to be very scientific in our descriptions, some little idea of the manner in which observations may be made is necessary. The first thing to see about is the ANGLE.



Right angles.

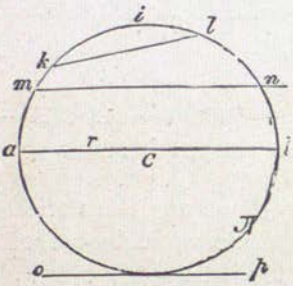
Suppose we draw four lines on a piece of paper, *ab* and *cd*. These intersect at a point, *m*. We have then four spaces marked out, and called *angles*. The four angles are in the diagram all the same size, and are termed *right angles*, and the lines containing them are perpendicular to each other.



Obtuse and acute angles.

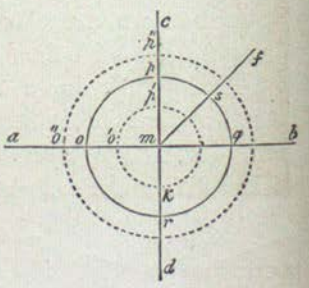
But by altering the position of the lines (*see* margin illustration), we have two pairs of angles quite different from right angles; one angle, *a' m' c'*, is smaller, while *a' m' d'* is much larger than the right angle. The former kind are called *acute*, the latter *obtuse* angles. We can therefore obtain a great number of acute angles, but only three obtuse, and four right angles around a given point, *m*.

The length of the sides of an angle have no effect on its magnitude, which is determined by the inclination of the lines towards each other. We now may consider the magnitude of angles, and the way to determine them. For this purpose we must describe a circle, which is figured in the diagram. But what is a circle? —A circle is a curved line which always is at the same distance from a certain fixed point, and the ends of this line meet at the point from which the line started.



The circle, etc.

If we fasten a nail or hold a pencil on the table, and tie a thread to it, and to the other end of the thread another pencil, we can describe a line around the first pencil by keeping the thread tightly stretched. This line is at all points at equal distance from the centre point. Any line from the centre to the circumference is called a *radius*, and a line through the centre to each side of the circumference is the diameter, or double the radius. The circumference is three (3·14) times the diameter. Any portion, say *k i l*, is an *arc*, and the line, *k l*, is the *chord* of that arc. A line like *m n* is a *secant*, and *o p* is a *tangent*, or a line touching at one point only.

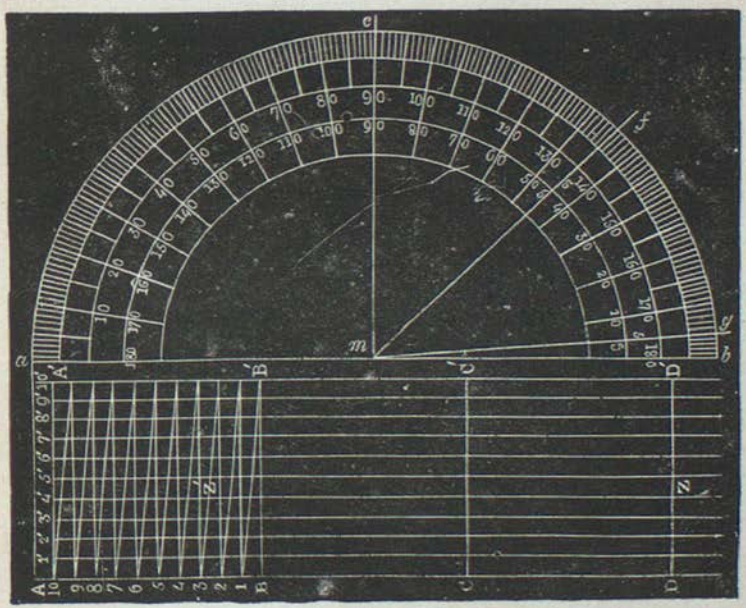


Circle and angles.

We may now resume our consideration of the angles by means of the circle. Let us recur to our previous figure of the right angles, around which we will describe a circle. We see that the portion of the circumference contained between the sides of the right angle is exactly one-fourth of the whole. This is

termed a *quadrant*, and is divided into 90°—the fourth of 360 equal parts or degrees into which the whole circumference is divided. The angle of 45° so often quoted as an angle of inclination is half a right angle. To measure angles an instrument called a *Protractor* is used.

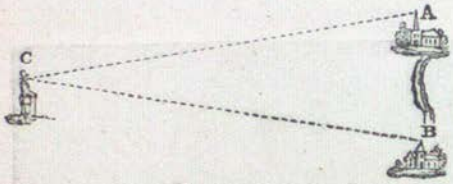
The Protractor, as will be seen from the accompanying illustration, is a semi-circle containing 180°. The lower



The Protractor.

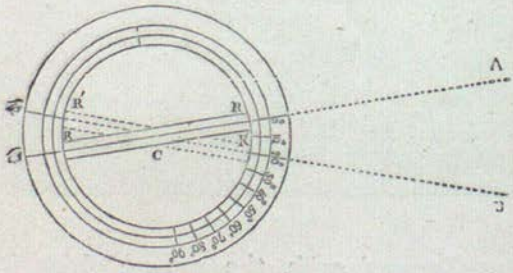
portion is a *diagonal scale*, the use of which will be explained presently. The Protractor measures any actual angle with accuracy. If we put the vertical point of the angle and the centre point of the circle together, we can arrive at the dimensions of the angle by producing the lines containing it to the circumference. An angle instrument, figured herewith, may be assumed as the basis of most apparatus for measuring angles. An index hand,

R R, moves round a dial like the hand of a clock, and the instrument is used by gazing first at one of the two objects, between which the angle we wish to determine is made—like the church steeples (illustration in margin) for instance. The centre of the instrument is placed upon the spot where lines, if drawn from the eye to each of the objects, would intersect. The index hand is then put at 0°, and in a line between the observer and the object, A. Then the index is moved into a similar position towards B, and when in line with it the numbers of degrees passed over (in this imaginary case 20), shows the magnitude of the angle.



Determination of distance.

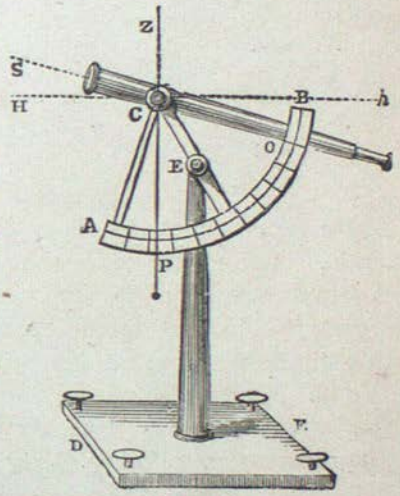
The simple quadrant is shown in the cut (page 19). This was so arranged that when any object in the horizon was being looked at through the telescope attached, a



Measuring angles.

plummet line is at 0°. But if the telescope be raised to C S, the quadrant will move, and the line will mark a certain number of degrees of the angle which a line if drawn from the star makes with the line of the horizon. The "Astronomical Quadrants" are as shown on page 22, and consist of a quadrant of wood strengthened and fitted

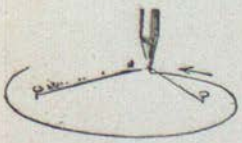
with a telescope. The circle is graduated on the outer edge, and a "vernier" is attached. The time is determined by the observation of the altitude of a star, and then by calculation finding out at what time the star would have the observed altitude. The quadrant is now superseded by circular instruments.



The quadrant.

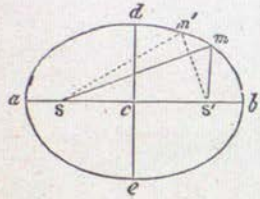
An ellipse is a flattened circle, or oval, and will be understood from the diagrams. Let us fix two pegs upon a sheet of paper, and take a thread longer than the distance between the pegs; draw with the pencil controlled by the thread a figure, keeping the thread tight. We shall thus describe an oval, or ellipse. The orbit of nearly all the heavenly bodies is an ellipse.

The *parabola* is another curved line, but its ends never meet; they become more and more distant as they are continued. The comets move in parabolic curves, and consequently do not again come within our vision unless their direction be altered.


Ellipse.

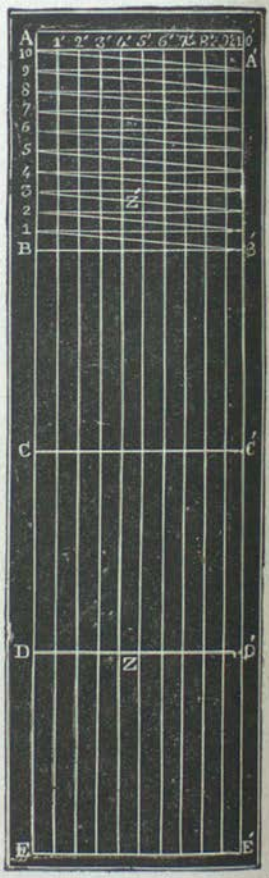
This figure has a long axis, *a b* (page 20); and perpendicular to this a short axis, *d e*, passing through the centre, *c*. The two points, S S' are called the *foci* of the ellipse; also, as is evident from the construction of the figure, any two lines drawn from the two foci, to any point of the circumference, for instance, S and S' *m*, or S *m'* and S' *m'*, etc., which represent the thread when the pencil is at *m* or *m'*,

are together equal to the larger axis of the ellipse. These lines, and we may imagine an infinite number of such, are called *radii vectores*. The distance of the foci, S or S′, from the centre, *c*, is called the *eccentricity* of the ellipse. It is evident that the smaller the eccentricity is, the nearer the figure approaches to that of the circle. The superficies of the ellipse is found by multiplying the two half axes, *ac* and *dc*, by each other, and this product by the number 3·14.



Ellipse.

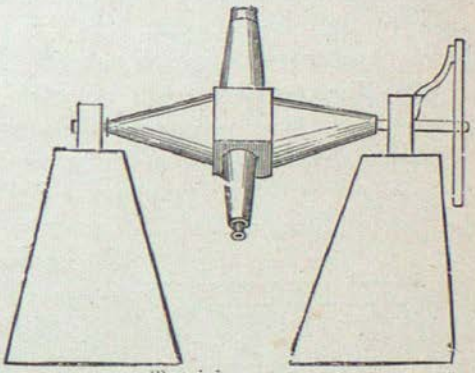
The *Diagonal Scale* is shown in the margin. It is used to make diagrams so as to bring the relative distances before the eye. The larger divisions represent, it may be, miles, or any given distance ; the figures on the left side tenths, and the upper range hundredths of a mile. So a measurement from Z to Z′ will represent two miles, we may say, with so many tenths and hundredths.



Diagonal scale.

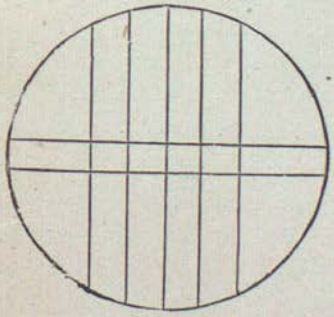
The Transit instrument is due to Roemer, a Danish astronomer. It consists of a telescope so constructed as always to point to the meridian, and rotates upon a hollow axis, directed east and west. At one end is a graduated circle. The optical axis of the telescope must be at exactly right angles to

the axis of the instrument, it will then move on the meridian. There is an eye-piece filled with two horizontal and five vertical wires, very fine, the latter at equal distances apart. The star appears, and the time it takes to cross is noted as it passes between each wire, and the mean of all the transits will be the transit on the meridian. For if we add the times of all the transits across the wires, and divide by five (the number of them) we shall get at a true result.



Transit instrument.

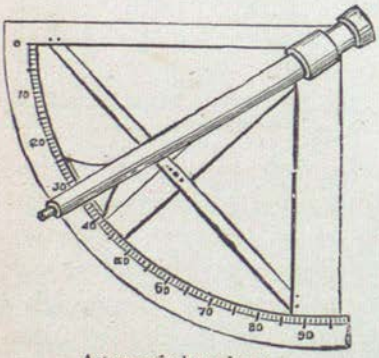
A good clock is also a necessary adjunct for astronomical observations, and the astronomical clocks and chronometers now in use record the time with almost perfect accuracy. The improvement in telescopes, the use of micrometers, etc., have greatly facilitated observations. In the transit clock we have a most useful timekeeper, for the ordinary clocks are not sufficiently accurate for very close observations. The sidereal time differs from solar time, and the twenty-four hours' period is calculated from the moment a star passes the meridian until it passes it again. The sidereal day is nearly four minutes shorter than the solar day, and the sidereal clock marks twenty-four hours



The eyepiece of transit instrument.

instead of twelve, like the old dial at Hampton Court Palace over the inner gate. The Chronograph has also been useful to astronomers, for by "pricking off" the seconds on a roller by itself, the observer can mark on the same cylinder the actual moment of transit across each wire of the instrument, and on inspection the exact moment of transit may be noted.

The *Equatorial* is another useful instrument, and by its means the whole progress of a star can be traced. The Equatorial consists of a telescope fixed so that when it been pointed at a certain star a clock-work movement can be set in motion, which exactly corresponds with the motion of the star across the heavens, and so while the star moves from its rising to setting it is under observation. Thus continuous observations may be made of that particular star or comet without any jerking or irregular movement.



Astronomical quadrant

We can thus see the uniform motion of the stars which go on in greater or lesser circles as they are nearer to or farther from the pole; and with the exception of the polar star, which, so far as we are concerned, may be considered stationary, every star moves round from east to west—that is, from the east of the polar star to the west of it, in an oblique direction. Therefore, as Professor Airy remarks, "Either the heavens are solid, and go all of a piece, or the heavens may be assumed to be fixed or immovable, and that we and the earth are turning instead of them."

The *Mural Circle* is another very useful instrument, and is used by calling to aid the powers of reflection of

quicksilver, in which a bright star will appear below the horizon at the same angle as the real star above the horizon, and thus the angular distance from the pole or the horizon of any star can be calculated when we know the inclination of the telescope. The Transit Circle is also used for this purpose, and is a combination of the transit instrument with the circle. In all calculations allowance must be made for refraction, for which a "Table of Refractions" has been compiled. From the zenith to the horizon refraction increases. The effect of refraction can be imagined, for when we see the sun apparently *touching* the horizon the orb is really below it, for the refraction of the rays by the air apparently raises the disc.

The clock and chronometer are both very useful as well as very common objects, but a brief description of the pendulum and the clock may fitly close our remarks upon astronomical apparatus and instruments. The telescope has been already described in a previous volume of this series, so no more than a passing reference to it has been considered necessary. We therefore pass on to a consideration of the measurement of time, so important to all astronomers and to the public generally.

Time was measured by the ancients by dividing the day and night into twelve hours each, then by sun-dials and water-clocks, or *clepsydra*, and sand-clocks. The stars were the timekeepers for night before any mechanical means of measurement were invented.

> "What is the star now passing?—
> The Pleiades show themselves in the east,
> The eagle is soaring in the summit of heaven."—EURIPIDES.

Sun-dials were in use in Elijah's time, and the reference to the miracle of the sun's shadow going back on the dial as a guarantee to Hezekiah, will be recalled at once by our readers. These dials were universal, and till sunset answered the purpose. But the hours must have been

very varying, and on cloudy days the sun-dials were practically useless.

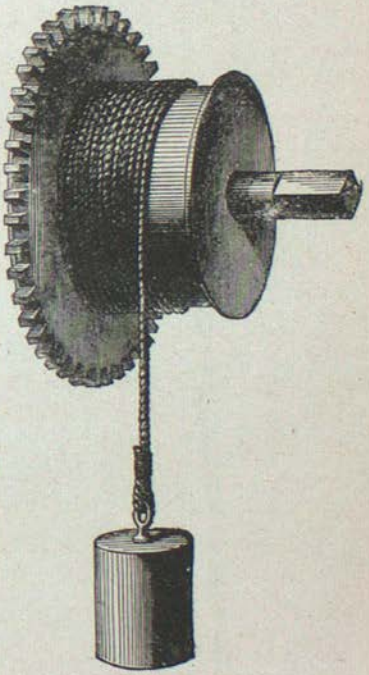
The water-clocks measured time by the dripping or flow of water, and they were used to determine the duration of speeches, for orators were each allotted a certain time if a number of debaters were present. This method might perhaps be adapted to the House of Commons, and speaking by the clock might supersede *clôture*. We find allusions to these practices in the orations of Demosthenes. Even this system was open to objection, for the vases were frequently tampered with, and an illiberal or objectionable person was mulcted of a portion of the water, while a generous or popular adversary had his clepsydra brimming full. Some of these water-clocks were of elegant design, and a Cupid marked the time with arrows on the column of the clock of Ctesibius, while another weeping kept up the supply of water. The motive power was the water, which filled a wheel-trough in a certain time, and when full this trough turned over, and another was filled. The wheel revolved once in six days; and by a series of pinions and wheels the movements were communicated more slowly to the pillar on which the time was marked for 360 days, or with other arrangements for twenty-four hours.

The repeating of psalms by monks also marked the time, for by practice a monk could tell pretty accurately how many paternosters or other prayer he could repeat in sixty seconds. At the appointed hour he then awoke the monastery to matins.

Nature also marks time for us—as, for example, the age of trees by means of rings—one for each year; and horses' teeth will guide the initiated to a guess at the ages of the animals, while the horns of deer or cattle serve a like purpose. But man required accuracy and minute divisions of time. He had recourse, therefore, to machinery and toothed wheels. Till the mechanical measurement of time was

adopted, the sunrise and sunset only marked the day, and the Italians as well as Jews counted twenty-four hours from sunset to sunset. This was a manifestly irregular method. To this day we have marked differences of time in various places and at Geneva we have Swiss and French clocks keeping different hours according to Paris or Berne "time." This, of course, is easily accounted for, and will be referred to subsequently.

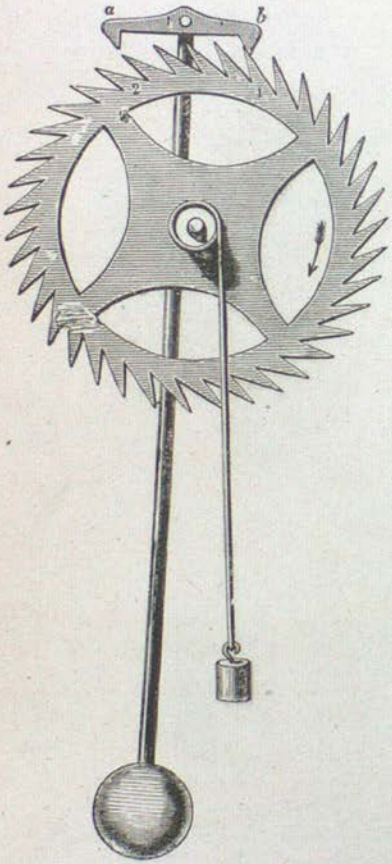
We have read that the first clock in England was put up in Old Palace yard in 1288, and the first application of the toothed wheel clock to astronomical purposes was in 1484, by Waltherus, of Nuremberg. Tycho Brahé had a clock which marked the minutes and seconds. If we had had any force independent of gravitation which would act with perfect uniformity, so that it would measure an equal distance in equal spaces of time, all the various appliances for chronometers would have been rendered useless. In the supposed case the simple mechanism, as shown in the margin, would have sufficed. The same effect would be produced by the spring, were it possible that the spring by itself would always uncoil with the same force. But it will not do so: we therefore have to check the unwinding of the cord and weight, for left to itself it would rapidly increase in velo-



Clock movement.

city; and if we likewise make an arrangement of wheels whereby the spring shall uncoil with even pressure all the time, we shall have the principle of the watch.

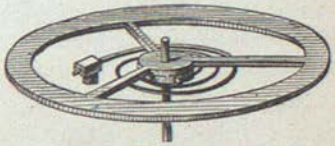
It is to Huygens that the employment of the pendulum in clocks is due, and the escapement action subsequently rendered the pendulum available in simple clocks, while the manner of making pendulums self-regulating by using different metals, has rendered time-pieces very exact. Of course the length of a pendulum determines the movement, fast or slow; a long pendulum will cause the hands of the clock to go slower, for the swing will be a fraction longer. A common pendulum with the escapement is shown (herewith). Each movement liberates a tooth of the escapement. The arrangement of wheels sets the clock going. The forms of pendulum are now very varied.



Pendulum and escapement.

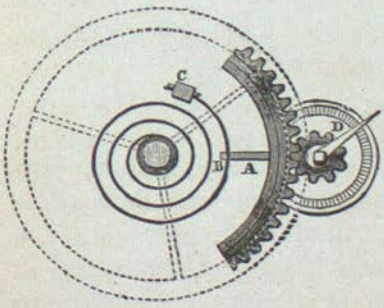
But in watches the pendulum cannot be used. The watch was invented by Peter Hele, and his watches were called "Nuremburg eggs" from their shape. The weight cannot be introduced into a watch, and so the spring and *fusee* are used. The latter

is so arranged that immediately the watch is wound and the spring is at its greatest tension, the chain is upon the smallest diameter of the fusee, and the most difficult to move. But as the spring is relaxed the lever arm becomes longer, and the necessary compensating power is retained. Watches without a "*fusee*" have a toothed arrangement beneath the spring.



Balance.

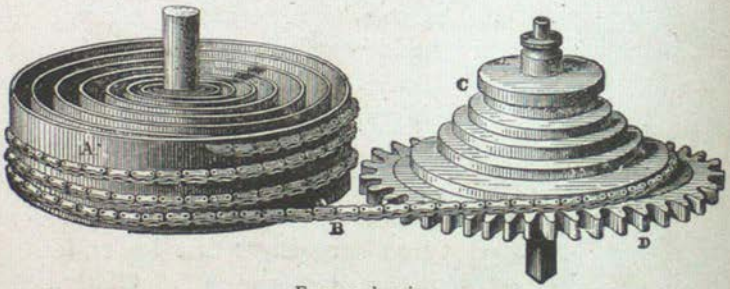
The *Pendulum.* A "simple" pendulum is impossible to make, for we cannot put the connecting line between the "bob" and the clock-work out of consideration, so "simple pendulums" are looked upon as "mathematical abstractions." The most modern clocks have what is called a "dead-beat" escapement, and a compensating pendulum Clocks are liable to alter by reason of the state of the air and varying temperature, and until all our clocks are placed *in vacuo* we must be content to have them lose or gain a little. There is a magnet arrangement by which the Greenwich Observatory clocks keep time by compensation, corresponding with the fall or rise of the syphon barometer attached to it. The description need not be added. We may here state that detailed descriptions of all the instruments used in the Observatory, together with full information as to their use, will be found in a very interesting work by Mr. Lockyer, entitled "Stargazing," to which we are indebted for some corrections in our summary.



Regulator.

We have spoken of solar time and sidereal time, and no

doubt someone will inquire what is meant by mean time —an expression so constantly applied to the Greenwich clock time. Stellar time, we have seen, corresponds to the daily revolution of a star or stars. Solar time is regulated by the sun, and this is the astronomical time generally observed, except for sidereal investigations. But the sun is not always regular; the orbit of the earth causes this irregularity partly. The earth moves faster in winter than in summer, so the sun is sometimes a little fast and sometimes a little slow. Astronomers therefore strike an average, and calculate upon a MEAN SUN, or uniform time-keeper. Mean time and true (apparent) time are at some



Fusee and spring.

periods the same—viz., on the 15th of April, on the 14th of June, on the 31st of August, and on the 24th of December. Twice it is after, and twice before it. The time occupied by this "mean" sun passing from the meridian and its return to it, is a mean solar day, and clocks and chronometers are adjusted by it.

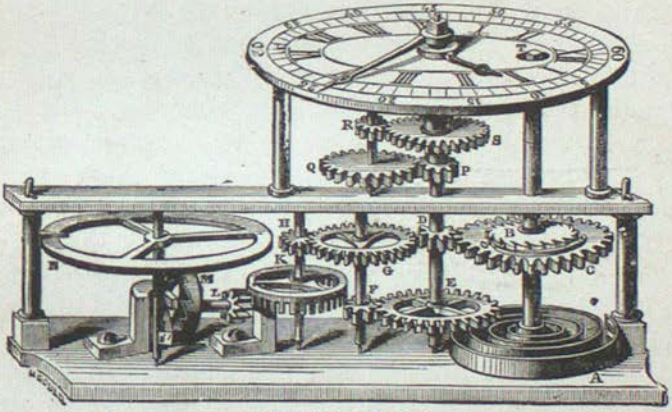
Twenty-four hours represents a complete revolution of the heavenly bodies. The mean solar time is $23^h\ 56'\ 4{\cdot}091''$, while twenty-four hours of mean time are equal to $24^h\ 3'\ 56{\cdot}55''$ of sidereal time. The difference between the times is given by Dr. Newcomb as follows, and is called the *Equation of Time* :—

DIFFERENCES BETWEEN MEAN AND APPARENT TIME.

February 10th	. .	True Sun 15 minutes slow.
April 15th	. . .	,, Correct.
May 14th	. . .	,, 4 minutes fast.
June 14th	. . .	,, Correct.
July 25th	. . .	,, 6 minutes slow.
August 31st	. .	,, Correct.
November 2nd	. .	,, 16 minutes fast.
December 24th	. .	,, Correct.

MEASUREMENT OF DISTANCES.

Before passing to consider the planetary system we must



Works of a clock.

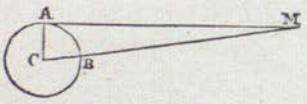
say a few words respecting the manner of ascertaining the distances of inaccessible objects, and by so doing, we shall arrive at an idea how the immense distances between the sun (and the planets) and the earth have been so accurately arrived at. To do this we must speak of *parallax*, a very unmeaning word to the general reader.

Parallax is simply the difference between the directions of an object when seen from two different positions. Now we can illustrate this by a very simple method, which we have often tried as a "trick," but which has been very

happily used by Professor Airy to illustrate the doctrine of parallax. We give the extract in his own words :—

"If you place your head in a corner of a room, or on a high-backed chair, and if you close one eye and allow another person to put a lighted candle upon a table, and if you then try to snuff the candle with one eye shut, you will find you cannot do it. . . . You will hold the snuffers too near or too distant—you cannot form any idea of the distance. But if you open the other eye, or if you move your head sensibly you are enabled to judge of the distance." The difference of direction between the eyes, which is so well known to all, is really a parallax. It can also be illustrated by the diagram herewith.

If two persons, A and C, from different stations, observe the same point, M, the visual lines naturally meet in the point, M, and form an angle, which is called the angle of *parallax*. If the eye were at M, this angle would be the angle of vision, or the angle under which the base line, A C, of the two observers appears to the eye. The angle at M also expresses the apparent magnitude of A C when viewed from M, and this apparent magnitude is called the *parallax* of M.

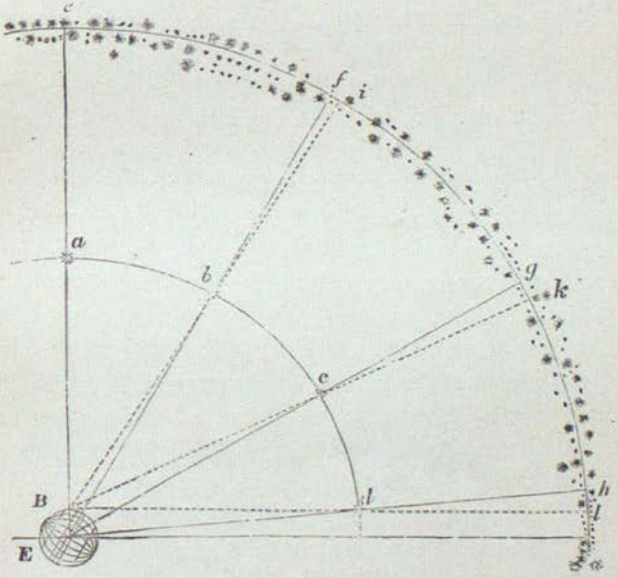


Parallax.

Let M represent the moon, C, the centre of the earth represented by the circle then A C is the parallax of the moon; that is, the apparent magnitude the semi-diameter of the earth would have if seen from the moon. If the moon be observed at the same time from A, being then on the horizon, and from the point, B, being then in the zenith, and the visual line of which when extended passes through the centre of the earth, we obtain (by uniting the points, A C M, by lines) the triangle, A C M.

Therefore, as A M, the tangent of the circle stands at right angles to the radius, A C, the angle at A is a right

angle, and the magnitude of the angle at C is found by means of the arc, A B, the distance of the two observers from each other. As soon, however, as we are acquainted with the magnitude of two angles of a triangle, we arrive at that of the third, because we know that all the angles of a triangle together equal two right angles (180°). The angle at M, generally called the moon's parallax, is thus found to be fifty-six minutes and fifty-eight seconds. We



Parallax explained.

know that in the right-angled triangle, M C A, the measure of the angle, M = 56′ 58″, and also that A C, the semi-diameter of the earth = 3,964 miles. This is sufficient, in order by trigonometry, to obtain the length of the side, M C; that is, to find the moon's distance from the earth. A C is the sine of the angle, M, and by the table the sine of an angle of 56′ 58″ is equal to $\frac{1652}{100000}$; or, in other words, if we divide the constant, M C, the distance of the

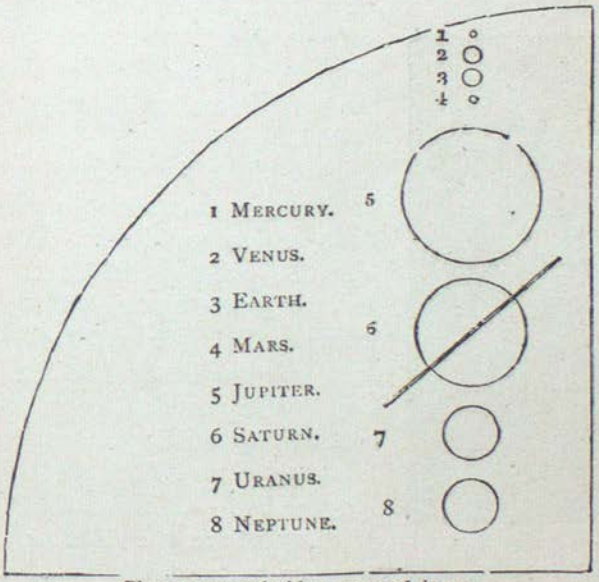
CHAPTER III.—THE SOLAR SYSTEM.

GRAVITATION—THE PLANETS—SIZE AND MEASUREMENT OF THE PLANETS—SATELLITES—FALLING STARS—COMETS—AEROLITES.

GRAVITATION is the force which keeps the planets in their orbits, and this theory, perfected by Newton, was partially known to Kepler. Newton brought this idea into practical shape, and applied it mathematically. We know that every object in the world tends to attract every other object in proportion to the quantity of matter of which each consists. So the sun attracts the planets, and they influence him in a minor degree. Likewise the moon and our earth reciprocally attract each other. But as the sun's mass is far greater than the masses of the planets he influences them more, and could absorb them all without inconvenience or disturbance from his centre of gravity. We have, in a former portion of this work, spoken of the law of universal gravitation, which is the mutual attraction of any two bodies to each other, and is directly proportioned to their *masses* (not size), and inversely to the square of their distances apart.

This law operates amongst the heavenly bodies, and it is to the never-changing action of gravitation that the planets are kept in their places. Let us see how this is effected. We have read of force, and motion, and rest. Every body will remain at rest unless force compels it to

change its position, and it will then go on for ever in a straight path unless something stops it. But if this body be acted on simultaneously by two forces in different directions, it will go in the direction of the greater force. Two equal forces will tend to give it an intermediate direction, and an equal opposing force will stop it. The last axiom but one—viz., the two equal forces in different, not opposing directions, gives us the key to the curving



Planets compared with a quarter of the sun.

line of the planetary motions. Were it not for the attraction of the sun the planets would fly off at a tangent; while, on the other hand, were not the impelling force as great as it is, they would fall into the sun. Thus they take an intermediate line, and circle round the centre of the solar system—the SUN.

The solar system consists of the sun and the planets which revolve in space around him. These stars are

called planets because they move in the heavens. We shall see that they have certain motions—going from east to west, from west to east, and sometimes they appear to be quite motionless. This change of place, appearing now at one side of the sun and now at another, has given them their title of "wanderers" (planets). Besides the planets there are comets and meteors, asteroids and satellites, all circling round the sun in more or less regular orbits. And there must be families of comets, and whole systems of meteors that have not yet appeared to us, and which make up the comets, as has been lately suggested.

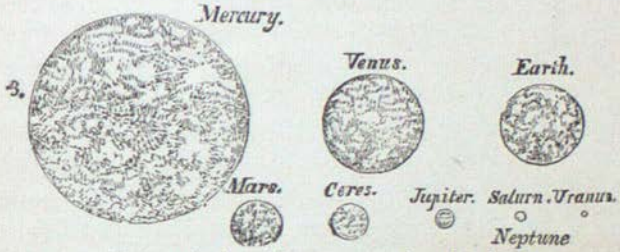


The Moon.

Five planets were known to the ancients, and were named after gods and a goddess: MERCURY, VENUS, MARS, JUPITER, SATURN. In later years a great number were discovered. We must, however, confine ourselves to the consideration of the principal ones, eight in number, including our own EARTH, URANUS and NEPTUNE completing the list. Of these VENUS and MERCURY are the inferior, or interior planets moving between us and the sun. MARS, JUPITER, SATURN, URANUS, and NEPTUNE are superior, or exterior, and pass quite round the heavens. All the planets are spheroids, and vary greatly in their magnitude, as will be seen by the illustration on page 37. Mercury, Mars, and Venus, are not so large as the Earth. The other principal planets are considerably larger than our globe.

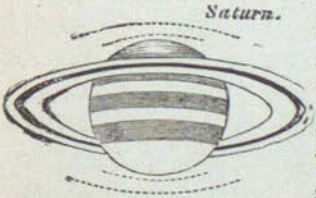
Mercury is the smallest of the planets, Venus being nearly as large as the earth. Then comes Mars, which,

though smaller than Venus, is larger than Mercury. Jupiter is the largest of all—the giant amongst planets, as Jove



Comparative size of the sun as seen from the planets.

was the ruler of the gods of mythology. Saturn comes next, though much smaller than Jupiter, but bigger than all the rest together. Next Uranus, then Neptune, larger than Uranus, but farther away from us. We shall speak more in detail about these in their order separately.





Sizes of planets.

Taking the earth as 1, the comparative VOLUMES of the planets are as follows:—

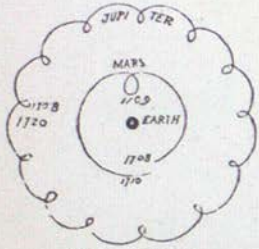


Sizes of the planets.

Mercury $\frac{1}{25}$, Venus $\frac{4}{5}$, Mars $\frac{1}{5}$, Jupiter 1300, Saturn 900, Uranus 80, Neptune 230. Sir John Herschel gives the following illustration of magnitudes and distances:—

"Choose any well-levelled field or bowling green; on it place a globe two feet in diameter; this will represent the sun. Mercury will be represented by a grain of mus-

tard seed on the circumference of a circle 164 feet in diameter for its orbit; Venus a pea, on a circle 284 feet in diameter; the Earth also a pea on a circle 430 feet; Mars a rather large pin's head on a circle of 654 feet; Juno, Ceres, Vesta, and Pallas grains of sand in orbits of 1,000 to 1,200 feet; Jupiter a moderate-sized orange on a circle nearly half a mile across; Saturn a small orange on a circle four-fifths of a mile; and Uranus a full-sized cherry, or small plum, upon the circumference of a circle more than a mile and a half in diameter."



Orbits of planets.

From an inspection of the following table the relative distances of the principal planets from the sun, their diameters, and other information respecting them may approximately be obtained. The dates of the discovery of the more modern pair are added :—

Names.	Diameters in English miles (about).	Distance from the sun (about).	Sidereal period of revolution.			Time of rotation on their axis.			Date of discovery
			d.	h.	m.	d.	h.	m.	
MERCURY	3,000	35,000,000	87	23	16	24	5	—	Antiquity
VENUS .	7,500	66,000,000	224	16	50	23	21	21	do.
EARTH .	8,000	91,000,000	365	6	9	23	56	4	do.
MARS . .	4,500	139,000,000	686	23	31	24	37	20	do.
JUPITER .	85,000	476,000,000	4,332	14	2	9	55	21	do.
SATURN .	70,000	872,000,000	10,759	5	16	10	16	—	do.
URANUS .	33,000	1,753,000,000	30,686	17	21	9	30	—	Herschel, 1781.
NEPTUNE	37,000	2,746,000,000	60,126	17	5	.	.		Leverrier and Galle, 1846.
THE SUN.	850,000	. . .	.	.	.	25	7·48		

Altogether there are a great number of planets and asteroids, which latter are minor planets circulating outside the orbit of Mars. They have nearly all classical names, such as Juno, Ceres, Vesta, Flora, Ariadne, Pallas, Pomona,

Thalia, etc., and are all at distances from the sun ranging between 200,000,000 and 300,000,000 of miles, the periods of sidereal revolution ranging from 1,100 to 3,000 days, so their years must be from four times to nine times as long as ours. Altogether about two hundred of the minor planets have been discovered, and they are all very much smaller than the earth ; some, indeed, being very tiny —only a few miles in diameter, but very massive. They do not appear to possess any satellites—at least, none have been discovered, for such very small bodies as they must be, supposing they exist, would be quite invisible even with our perfected instruments.



Mars.

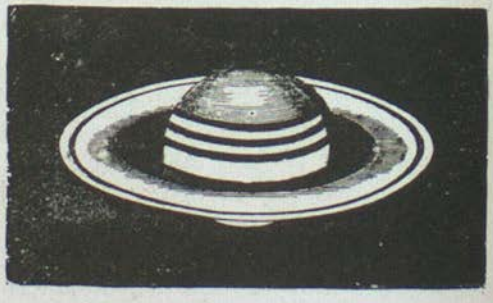
SATELLITES, however, or "planetary moons," as they are sometimes designated, are plainly perceived attending upon the great planets. There are twenty of these at present under observation. One we are all familiar with, and the moon, *par excellence*, lends a beauty to our nights which no other light that we can enjoy or command can ever do. It is remarkable that only this moon is specially mentioned in the Bible in connection with the sun. The stars are usually grouped, although, of course, the sun and moon are equally "stars" in the firmament. Mars possesses two moons and Jupiter four ; Uranus also rejoices in the latter number ; Neptune, like the Earth, has only one. It is reserved for Saturn to outstrip all the rest in his attend-

ants, for no less than eight satellites wait upon that enormous planet. No doubt there are many more of these moons to be found, and every year will doubtless bring us further knowledge respecting them. Mars' moons were only discovered very lately (in 1877), although they were known to exist; but being very small, unlike the others, they were missed. So we may conclude that the remaining satellites will remain for some time undiscovered, even if they actually are in existence. Jupiter's moons are supposed to be as large as our own moon; Neptune and Uranus can boast of equally sized attendants. But it is impossible to estimate the riches of astronomical lore which are beyond our ken. Millions of tiny planets are believed to exist, but their immense distance from us precludes all investigation. We are but mites in the scale.



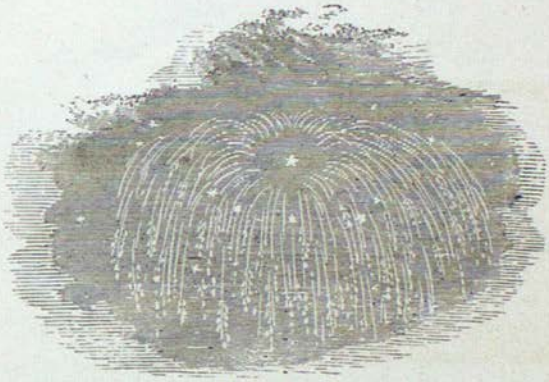
Jupiter.

METEORS, to which we have already referred, are small erratic bodies rushing through the planetary system, and getting hot in the process, appear in the atmosphere surrounding our earth as "shooting stars." Some of these falling bodies have reached the earth, and several can be seen in the British Museum. Numbers, of course, are burnt up before they reach us, and who can tell what destruction such a



Saturn.

catastrophe may represent, or whether it be or be not an inhabited world which has thus plunged to destruction by fire? They are of a metallic or stony nature. On certain



Meteor shower.

nights in August and November it has been calculated that these meteors will appear. They fall from certain constellations apparently on these occasions, and are called



Star shower.

after their names—as Leonides, from Leo, in the November displays.

The star-showers at times attain the dimensions of

a very beautiful display of rockets. Millions of them rush round the sun; and when, as occasionally happens, our earth comes near them, we have (as in 1866) a grand display of celestial "fireworks." But the individuals composing the mass of falling stars are very small. These meteors are very much like the comets we in 1881 had an example of, and it has been lately suggested that there is a great degree of affinity between the comets and the meteors;—in fact, that a comet is merely an aggregation



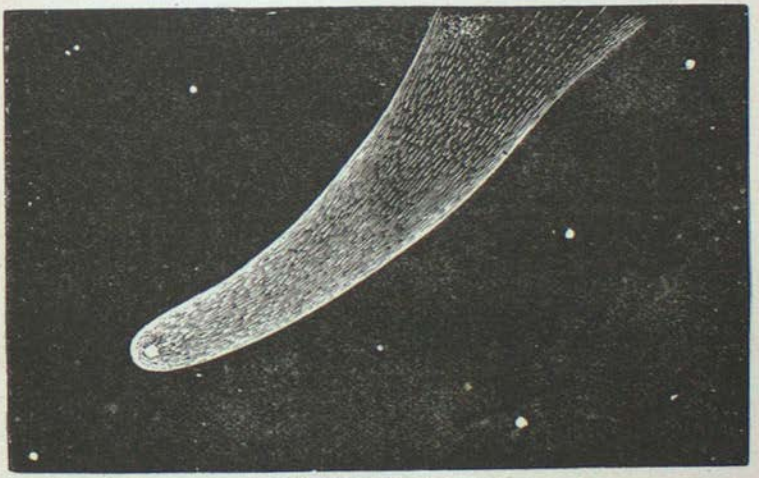
Halley's Comet in 1456.

of meteors. They have been supposed to be bodies of burning gas. Their mass is very great, and their brilliant tails are many millions of miles in extent.

Comets are thus distinguished by their tails, and differ very much in their orbits from the planets. The latter are direct in their wanderings, but comets are most irregular and eccentric. The name bestowed upon comets is from the Greek *Kome*, hair; for when the comet recedes from the sun the "tail" may be said to come out of the head, and appear as a hair in front, so to speak. But though all

comets have tails, there are many luminous bodies (classed with comets) which have no tails.

The comet which created the most excitement was Halley's in 1456, of which we append an illustration (page 42). A comet had been observed in 1607, and Halley made a calculation that it would reappear in 1758. The calculation for its actual reappearance was made by Claivant, and the expected visitor passed the perihelion in March 1759. This comet, on its first appearance at Constantinople,

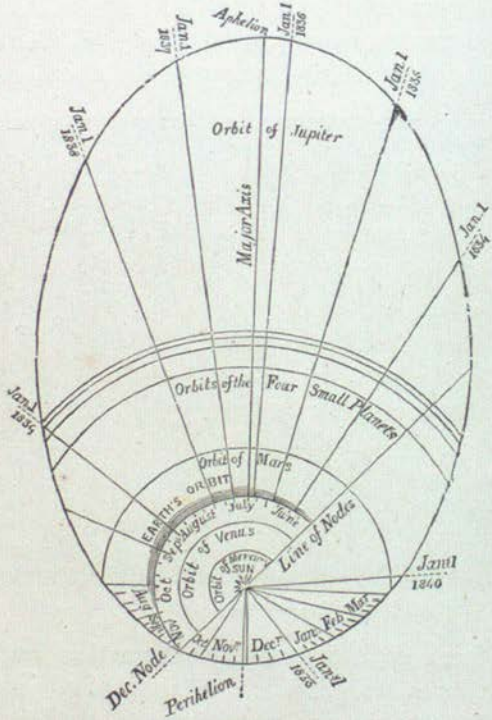


Great comet of 1811.

is said to have caused much consternation, and Christians regarded it as a "sign," for the Turks had just then captured Constantinople, and were threatening Europe. Pious people included it in their supplications for deliverance from their most dreaded enemies, and "Lord, save us from the Turks, the devil, and the comet," was a common prayer.

There have been several very beautiful comets. Encke's, Coggia's, etc., and the comet of 1858 (Donatis) must be in the recollection of middle-aged readers. Others came

in 1861 and 1874. In 1881 two comets appeared. Some comets of antiquity were very remarkable, and are reputed to have equalled the sun in magnitude. One tail is usually supposed to be the distinguishing mark of a comet, but in 1774 one appeared with six tails arranged something like a fan. Sometimes the tail is separated

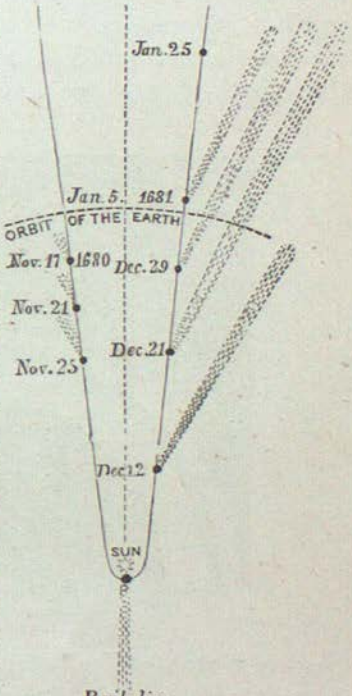


Path of Biela's Comet.

from the head. Of the actual consistency of comets we cannot give any lengthened details. They apparently consist of elements similar to the meteors—namely, of solid masses, and have been supposed to be aggregations of meteors. Some appear at regular intervals, and their approach can be determined with accuracy. Of course

we only see those which are attracted by the sun, or those which revolve in the solar system. There must be thousands of other comets which we never see at all.

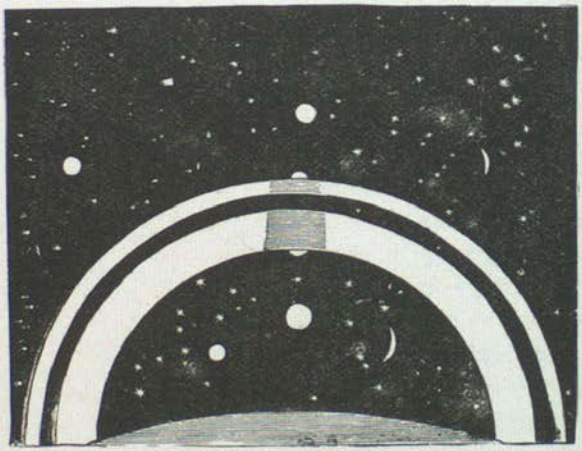
The diagram below represents a portion of the path of the comet of 1680. This visitor pursued its course for two months at a velocity of 800,000 miles an hour. The tail was estimated to extend 123,000,000 of miles, and a length of 60,000,000 of miles was emitted in two days. When this great comet was approaching the sun, or its perihelion as such approach is termed, three minutes more would have seen it rush into the orb had its enormous pace been slackened, but as it was proceeding so rapidly, and being just then 144,000 miles away, it escaped. We can scarcely estimate the results of such a collision. This comet appeared B.C. 34, and again at intervals of about 575 years. It may be expected in 2255. It is to Halley that the discovery of the elliptical orbits of comets is due.



Path of comet, 1680.

M. Biela's comet was the cause of much anxiety in 1832, for a collision with the earth was apprehended. Fortunately a month intervened between the period at which the comet was expected at a certain place in the system and the earth's arrival at that spot, so, as it happened, about 60,000,000 of miles intervened. We cannot say what the exact effect of such a collision would be, but

some wonderful atmospheric phenomena and increased temperature would certainly result from the contact. Now the comet is supposed to have an effect upon the vintage, as "comet" wines are regarded with much favour. If comets, as is believed, do consist partly of solid particles, a collision might be unpleasant; but the weight is, as a rule, a mere nothing compared to their vapoury volume, which is enormous. That the tails must be of a very attenuated medium is evident, as we can see the stars through them, and we know that a very thin cloud will



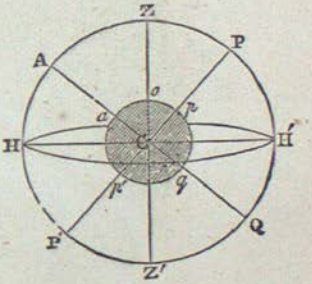
The heavens as seen from Saturn.

obscure a star. The "menacing" comet, mentioned in the *Spectator* February 1881, will not do much damage, so the scare was needless, as Mr. Proctor has explained.

AEROLITES, or "Meteorites," are falling bodies (meteors), which reach the earth in solid form. The greater mass of falling stars are burnt up ere they reach us, or are dissipated in space. But many instances of aerolites descending might be adduced. They usually consist of metals,

such as iron and nickel mixed with sulphur, magnesia, and silica. The theory concerning falling stars has been already mentioned.

We have thus far taken a brief general view of the solar system, with a few of the phenomena of the heavens. Our next step will be to consider the sun, the planets, and the asteroids, according to the order of magnitude. The asteroids we cannot consider separately, but the sun, moon, earth, and the principal planets will yield us much interesting information as we examine them more closely. We shall then, as far as possible, look into the domain of the fixed stars, constellations, and the nebulæ, commenting, as we proceed, upon the varied celestial and terrestrial phenomena connected with the movements of the heavenly bodies. As is due to the great centre of our system, we will commence with the SUN. But before proceeding to do so, we must say a few words about the motion of the heavenly bodies—that is, the *apparent* motion of the rising and setting of the sun and stars.



Celestial axis.

The attentive observation of the starry heavens, even during a single night, will convince us that all the visible stars describe circles which are the smaller, the nearer the stars are to a certain point of the heavens, P (page 47). In close proximity to this point there is a tolerably bright star, called the *Pole Star*, which has scarcely any motion, but appears to the eye as always occupying the same position. Hence a line, PP′, drawn from this star, through the centre of the earth, *c*, represents the axis around which all the heavenly bodies perform their apparent motions. The part of the celestial axis, P P′, passing through the earth, is the earth's axis; the

north pole, of which p is on the same side as the pole star, and the south pole, p', is on the opposite side.

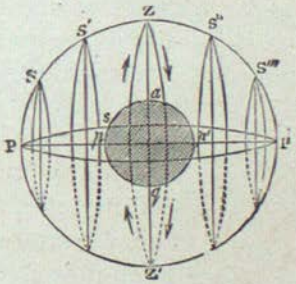
We have, therefore, by the aid of the stars, determined the position of the earth's axis, and by this latter we can assign to the equator its proper place. For if pp' be the earth's axis, aq' is the greatest circle drawn round the earth, equally distant from both poles, and the plane of which cuts the earth's axis at right angles.



Great Nebulæ in Orion.

Furthermore, let us suppose the plane of the equator to be extended till it reach the celestial concave; we thus find the place of the celestial equator, A Q, or *equinoctial*, as it is generally termed in opposition to the equator, which always means the terrestrial equator. The equinoctial divides the heavens into the northern and southern hemispheres. We cannot actually describe the equinoctial and make it visible, but we can imagine its line of direction by observing those stars through which it passes.

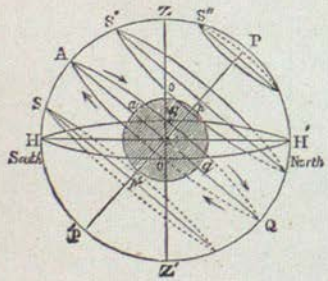
We are now in a condition to assign to an observer different stations in relation to the earth's axis on the earth's surface, which will essentially modify the aspects under which celestial phenomena are represented One of these stations may be supposed to be at one of the two poles, for example, at *p*, or at any one point of the equator, as at *a*, or, finally, on any portion of the surface of the earth which lies between the pole and the equator, as, for example, *o*.



CHAPTER IV.—THE SUN.

MOTION OF THE SUN—THE SEASONS—CHARACTER OF THE SUN—SUN SPOTS—ZODIACAL LIGHT.

SUPPOSE that we rise early in the morning we shall, as the reader will say, see the sun rise—that is, he appears to us to rise as the earth rotates. By the accompanying diagram we can understand how Sol makes his appearance, and how he comes up again; not, it will be observed, after the manner stated by the Irishman, who declared that the sun "went down, and ran round during the night when nobody was looking." The earth rotates from west to east, and so the sun appears to move from east to west. If we look at the diagram we shall see that after rising at O, the sun advances towards the meridian in an oblique arc to A, the highest or culminating point—midday. He then returns, descending to W; this path is the diurnal arc. At Q similarly, during his passage in the nocturnal arc, he reaches the lowest or inferior culmination. H H′ is the meridian.

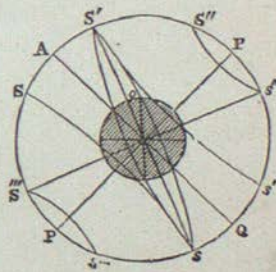


Sun's motion.

On the 21st of March, this path brings the sun on the "equinoctial" line mentioned at the close of the last

chapter. Day and night are then of equal duration as the arcs are equal. So this is the *Vernal* (or spring) *Equinox.* Some weeks after the sun is at midday higher up at S′, so the diurnal arc being longer, the day is longer. (Z is the zenith, Z′ is the nadir, P P′ is the celestial axis). From that time he descends *again* towards the equinoctial to the autumnal equinox, and so on, the diurnal arc becoming smaller and smaller until the *winter solstice* is reached (S).

From what has been previously said, it is evident that the sun has a twofold apparent motion—viz., a circular motion obliquely ascending from the horizon, which is explained by the rotation of the earth, and by our position, *o*, to the earth's axis, *p p′*, and also by a rising and setting motion between the solstitial points, S and S′, which causes the inequality of the days and nights. Independently of the daily motion of the sun, we observe that at the summer solstice, on the 21st of June, at midday, the sun is at S′, and one half year later—viz., on the 21st of December, at midnight, the sun is at *s*, from which he arrives again in the space of half a year at S′; so we are able to represent this annual motion of the sun by a circle, the diameter of which is the line, S′ *s*. This circle is called the *Ecliptic.*

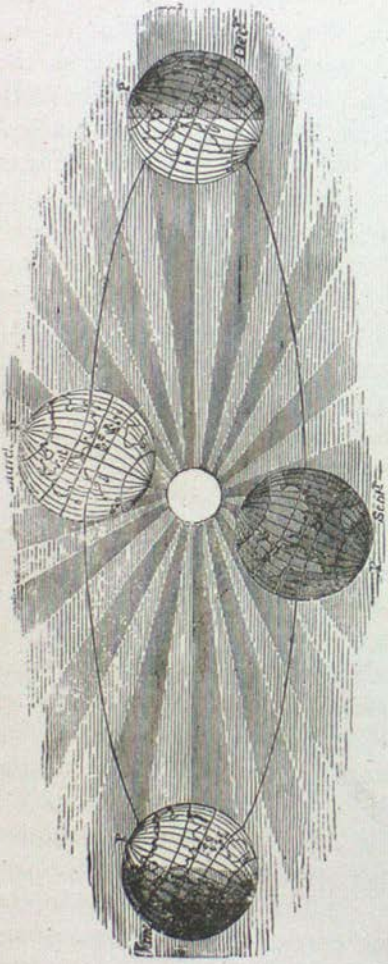


The ecliptic.

The plane of the ecliptic, S′ *s*, cuts the plane of the equinoctial, A Q, at an angle of 23½°, and the axis of the ecliptic, S‴ *s*″, makes the same angle with the axis of the heavens, P P. The two parallel circles, S′ *s*′ and S *s*, include a zone extending to both sides of the equinoctial, and beyond which the sun never passes. These circles are called the *Tropics*, from τρέπω, *I turn*, because the sun turns back at these points, and again approaches the equinoctial. The parallel circles, S″ *s*″, and S‴ *s*‴, described

by the poles of the ecliptic, S‴ *s*″ about the celestial poles, P P, are called the *arctic* and *antarctic circles.*

Whenever the sun crosses the equinoctial, there is the equinox; but the points of intersection are not invariably the same every year. There is a gradual westerly movement, so it is a little behind its former crossing place every year. (*See* diagram, page 53.)

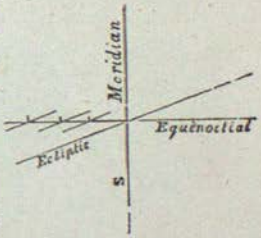


[This is the "Precession of the Equinoxes," because the time of the equinoxes is hastened, but it is really a retrograde movement. Hipparchus discovered this motion, which amounts to about fifty seconds in a year. So the whole revolution will be completed in about 28,000 years.]

It is obvious, then, that the sun is the most important star in the universe; and when we come to speak about the earth we shall consider the seasons, etc., more fully. Now we must endeavour to explain what the sun is like, and this can only be done with specially darkened glasses, for a look at the sun through an ordinary tele-

scope may result in great, if not permanent, injury to the eye.

The sun is not solid so far as we can tell. It is a mass of "white-hot" vapour, and is enabled to shine by reason of its own light, which the planets and moon cannot do; they shine only by the sun's reflected light. So we may conclude the sun to be entirely gaseous, but, thanks to the recent researches in *spectrum analysis* (already explained), by which the light of the sun has been examined by means of the spectroscope, and split up into its component colours, Mr. Lockyer and other scientists have discovered that a number of elements (metals) exist in the sun in a fused, or rather vapourous state, in consequence of the intense heat. Hydrogen exists in the sun, with other gases unknown to us here, and many metals, discovered by their *spectra*, which are the same under similar circumstances.



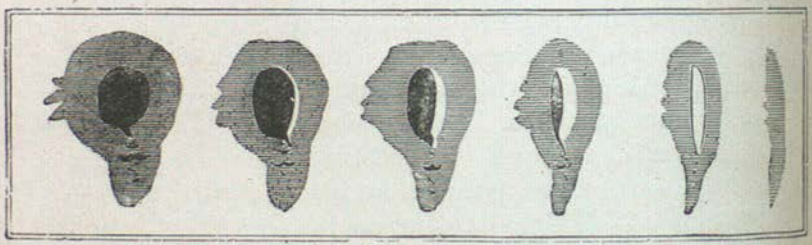
Precession of Equinoxes.

The sun is supposed to be spherical in shape,—not like the earth, flattened at the poles,—and to be composed of materials similar to what the earth is composed of, and what it would be if it were as hot as the sun is. Thus we can argue by analogy from the *spectra* of earthly elements, that, as the sun and star light gives us similar *spectra*, the heavenly bodies are composed of the same elements as our globe. We can thus form our opinion of the sun's constitution. Mr. Neisen says:—

"With the aid, therefore, of the additional information given us by the spectroscope, it is not very difficult to form a true idea of the probable condition of the surface of the sun, which is all that we can see. It is the upper-lying strata of a very dense atmosphere of very high temperature—an atmosphere agitated by storms, whirlwinds, and cyclones of all kinds, traversed by innumerable currents,

and now and then broken by violent explosions. Above the brilliant surface which we see is a less dense and somewhat cooler upper stratum, which, though hot enough to shine quite brightly, is quite invisible in the presence of the brighter strata beneath it."

SUN SPOTS, as they are generally called, are hollows in the sun's vapoury substance, and are of enormous extent; and there are brilliant places near those spots, which are termed *faculæ*. These spots have been observed to be changing continuously, and passing from east to west across the sun, and then to come again at the east to go over the same space again. Now this fact has proved



Sun spots.

that the sun turns round upon his axis, and although he does not move as we imagine, from east to west, round the earth, the orb *does* move—in fact, the sun has three motions: one on his axis; secondly, a motion about the centre of gravity of the solar system, and a progressive movement towards the planet Hercules.

If we examine the surface of the sun through a proper telescope, we shall find that the even surface we can plainly distinguish at sunset is marked, and the brightness is greater towards the centre of the orb. We can perceive various irregularities; we shall find spots, faculæ (little torches), etc. These spots were discovered by Galileo and other astronomers, and were, as we have stated, found

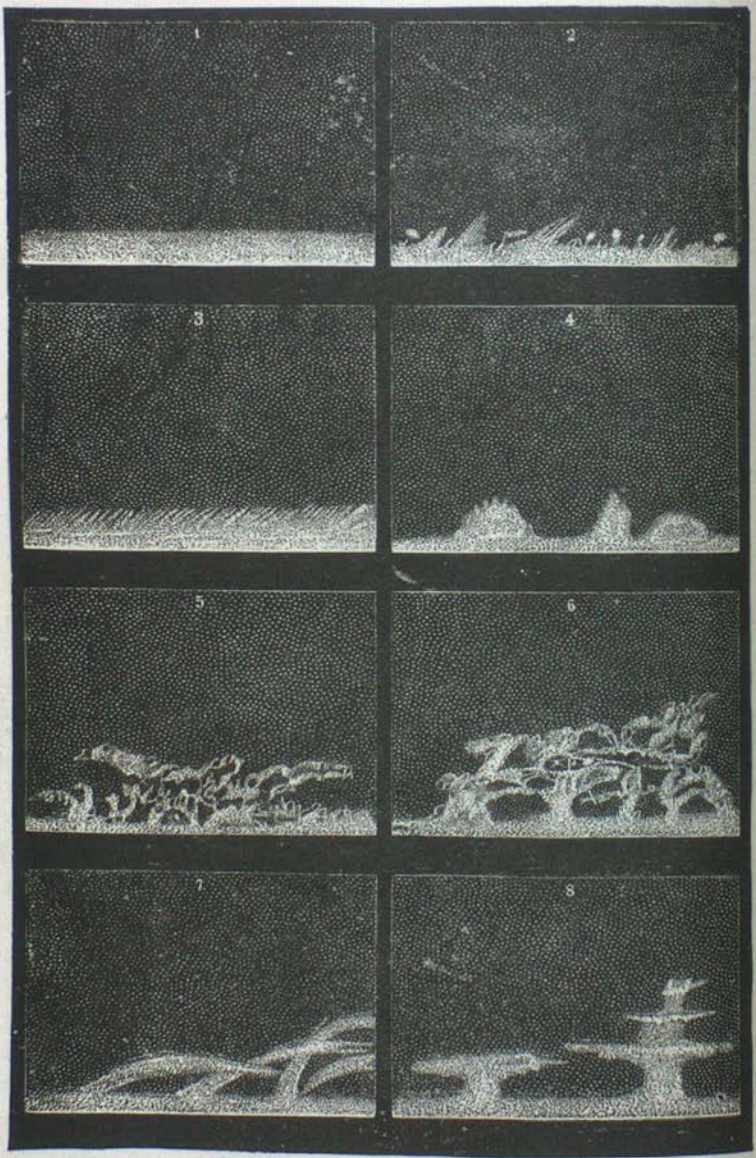
to be surface markings, and not a series of bodies passing between the earth and the sun. The rotation of the sun was measured, and it was found that the orb revolved in about 25⅓ days, and in such a manner as to be slightly inclined to the plane of the ecliptic.

Herschel observed a spot at least 50,000 miles in diameter, which is more than six times the diameter of the earth. The sun spots are observed to be constantly changing, and are naturally observed differently as the revolution proceeds. The dark pole, or "nucleus" (*umbra*), as it is called, is surrounded by a less dark surface called the *penumbra*, but the umbra is not really dark; it is extremely bright when viewed alone, as has been proved by Professor Langley, while the heat is even greater in proportion. But the umbra of a sun spot must be below the level of the penumbra, for the shape changed as the sun revolved on its axis. The penumbra was wider on the side nearest the edge of the solar disc, and the umbra may be due to the uprushing or downpouring of gas or vapour like "whirlpools in the solar atmosphere."

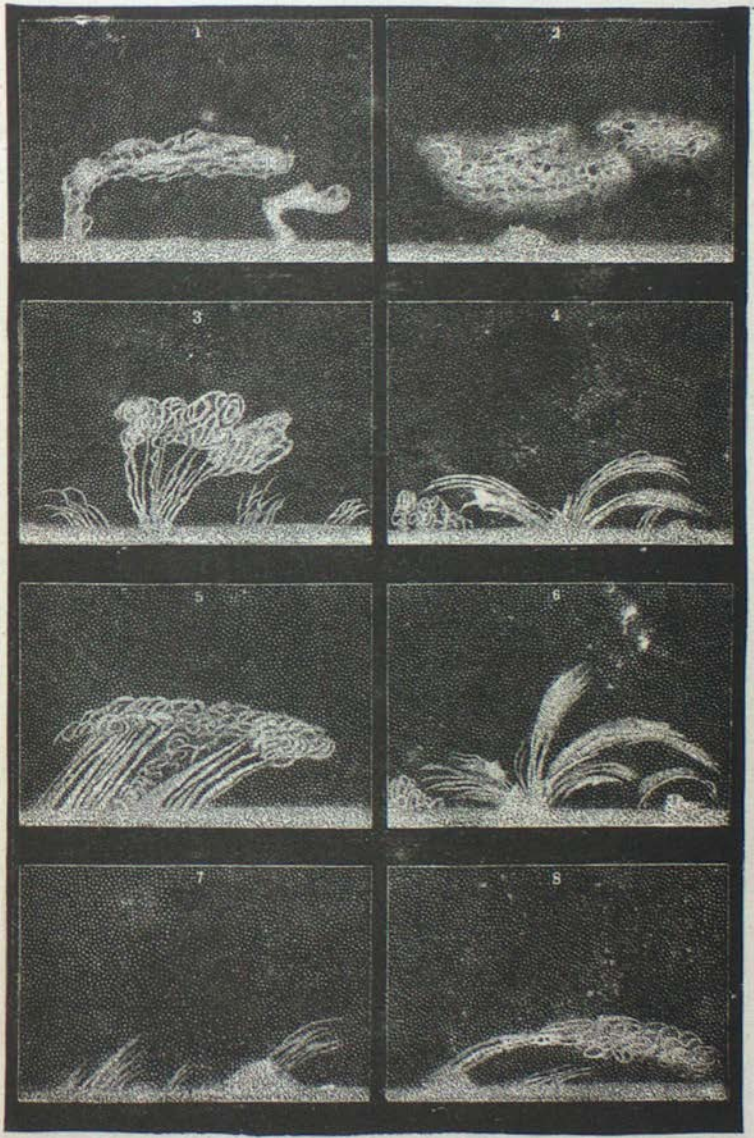
Near the sun spots the long streaks, or *faculæ*, are often observed by the borders of the disc, and a transition of the luminous part of the photosphere* into darkness has been observed, and bright bridges crossing the spots, and then gradually getting dark, were seen by M. Chacomac. The sun spots vary in direction, but the same general course is continued. Sometimes they describe curves, sometimes lines.

During solar eclipses the sun exhibits what are termed "red prominences," which are the luminous vapours existing around the sun. When the orb is eclipsed, we can see the bright-colour vapours shooting out from underneath the dark shadow, and this light is termed the "coronal atmosphere"; the vapours are called the sun's

* The bright part of the sun.

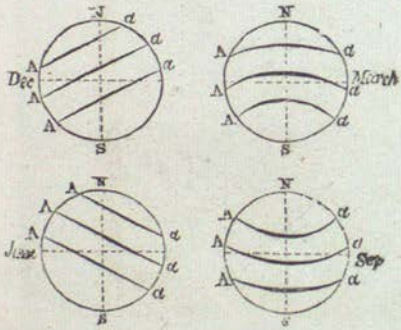


Solar prominences.



Solar prominences.

chromosphere. In the coronal atmosphere are certain curious shapes of vapour thrown up, and frequently changing,—projecting, in fact, from the gaseous envelope. These red prominences were first observed in 1842, and in 1851 it was proved that they appertained to the sun, for the moon hid them as the eclipse began. Before the prominences were discovered, the red light surrounding the solar disc was known, and called the "sierra" (now chromosphere), or chromatosphere. "The luminosity of these prominences is intense," says Secchi, "and they rise often to a height of 80,000 miles, and occasionally to more than twice that; then bending back, they fall again upon the sun like the jets of our fountains. Then they spread into figures resembling gigantic trees, more or less rich in branches." We give some illustrations of the appearances of these prominences.



Direction of sun spots.

The *zodiacal light* is often observed It is a glow, and frequently of a rosy tint. It may be seen in England in March or April before sunset, or in the autumn before sunrise; and it is doubtful whether it be a terrestrial or an extra-terrestrial light—a lens-shaped object surrounding the sun. Some philosophers maintain that the light is caused by multitudes of minute bodies travelling round the sun; but Herr Gronemann has lately fully discussed the observations, and the drift of his contention is under stated:—

There are valid observations against two items in the support of the old theory—viz., the affirmed connection of the evening and morning cones seen on the same night (if the corresponding sides be prolonged), and the partici-

pation of the cones in the daily motion of the heavens. The zodiacal light is sometimes seen when daylight has not yet disappeared ; and, on the other hand, it sometimes fails to appear, though there is complete darkness. There would seem to be a real lengthening and shortening. It has been observed by Schioparelli, that the light is much more difficult to make out when it passes through the meridian, than when it is only 30° above the horizon, and is less easily seen when the air is clearest than when a sort of mist is present. Indeed, the bright parts of the Milky Way may be seen to be weakened by mist, while



On the sun's disc.

the zodiacal light at the same height is unaffected. The zodiacal light has temporary variations of light intensity, and it shows from time to time remarkable changes of form and position, so sudden and short as to be hard to explain on the planetary hypothesis. The elongations of the cones show a half-yearly period, which is independent of the transparency of the air. The cone follows the observer northwards or southwards, so that there is no parallactic action ; and this peculiarity (so adverse to the extra-terrestrial hypothesis) cannot be explained by reflection or absorption of light. As to spectroscopic observations,

the author finds (1) that the zodiacal light consists partly of proper light; (2) that its connection with polar light is but secondary, temporary, and accidental; (3) that the cause of the second phenomenon is such that it may strengthen the zodiacal light and modify its spectrum; and (4) that the results of spectrum analysis rank with other arguments tending to find the source of the zodiacal light in the neighbourhood of the earth (like the polar light). Herr Gronemann, then, thinks the zodiacal light a terrestrial phenomenon, though he will not say that it cannot be influenced by cosmic action. He throws out the suggestion that the cone may be a kind of optical illusion, arising from some fine matter—gas or dust—being more accumulated near the observer in one direction than another. The apparent length of the cone might be conditioned by the conical shadow of the earth, and the changes of length be due to cosmic and electric influences. In any case, there is need of a more scientific theory than the old one.

We may conclude our brief notice of the great luminary to which we are indebted for everything, by a *resumé* of his distance from us, his diameter, and a few other plain facts and figures. In the first place the actual distance of the sun from the earth has never accurately been determined, but perhaps the next transit of Venus will assist the observers to a nearer estimate. It is quite sufficient for our purpose, however, to state that the sun's distance from the earth is 92,000,000 of miles. The distance varies in winter and summer. In the former period the sun is *nearer* than in summer, and yet as the rays strike over us, and pass us, as it were, we feel less heat. When, as in summer, we are more in the focus of the rays, we feel the greater heat.

We have already spoken of *parallax*, and it is by finding the solar parallax that the distance of the sun from us

is found. This parallax has not been exactly ascertained, or rather authorities differ, and as difference of 0·01″ in the solar parallax means something over 100,000 miles of distance, it is evident that exactness is almost impossible. If 8″·80 be settled as the solar parallax, 92,880,000 miles is the distance of the sun from the earth. If 8″·88 be taken we have nearly 92,000,000 exactly.

The *volume* of the sun is 1,253,000 times that of the earth, and yet the *density* of the former is only about one-fourth of the latter, so the attraction of gravitation at the sun must be more than that of the earth's surface twenty-seven times. A body dropped near the surface of the sun would fall 436 feet in the first second, and have attained a velocity of ten miles a minute at the end of the first second. The diameter of the sun depends in our calculations upon its distance from the earth. If we suppose that to be 92,880,000 miles, the diameter is 866,000 miles. If we take 91,000,000 of miles as the distance from the earth the diameter is 850,467 miles. The sun makes (apparently) the circuit of the heavens in 365 days, 6 hours, 9 minutes, and 9·6 seconds; the transit from one vernal equinox to the next being only 365 days, 5 hours, 48 minutes, 48·6 seconds, owing to the precession of the equinoxes already mentioned.

When we consider the power and grandeur of the sun we may well feel lost in the contemplation. The sun balances the planets and keeps them in their orbits. He gives us the light and heat we enjoy, and coal-gas is merely "bottled-up sunlight." In darkness nothing will come to maturity. We obtain rain and dew owing to the sun's evaporative power; and no action could go on upon earth without the sun; and yet we receive only about $\frac{1}{2070650000}$ part of its heat and light.

As to the colour of the sun, Professor Langley states that it is really blue, and not the white disc we see. The

whiteness is due to the effect of absorption exerted by the vapourous metallic atmosphere surrounding our luminary; and if that atmosphere were removed, his colour would change.



CHAPTER V.—THE EARTH.

FORM OF THE EARTH—MOTION OF THE GLOBE—RATE AND MANNER OF PROGRESSION—LATITUDE AND LONGITUDE—THE SEASONS.

WE have learnt from our books on Geography that the earth is shaped like an orange,—that is, our globe is round and flattened slightly at the "poles," and we can easily see that the earth curves away, if we only try the experiment mentioned in a foregoing chapter—viz., how far a person standing (or lying) on the ground can see on a level. Our power of eye-sight is not limited to three or four miles, but a man of ordinary height standing on the plain cannot see more than three miles, *because the earth is curving away from him.*

We know that at the seaside we can see ships gradually appear and disappear. When approaching us the masts and top-sails appear first, then the main-sails, and then the ship itself. A sailor climbing up the mast can see farther than the captain on deck, because he can see over the curve, as it were. When the vessel is at a considerable distance we see her "hull down" as it is termed, —that is, only her sails are visible to us, and at last they disappear also. If we want any other proof that the earth is round we can see when an eclipse takes place that the shadow on the moon is circular. So we may be certain

of one fact; the earth is round, it is a globe. So much for the rotundity of the earth.

But the earth appears to us, except in very mountainous districts, as being almost a plane. This is because of its extent; and even from very high mountains we can only see a very small portion of the earth, and so, on a globe sixteen inches in diameter, the highest hills would be only about $\frac{1}{100}$ of an inch, like a grain of sand.

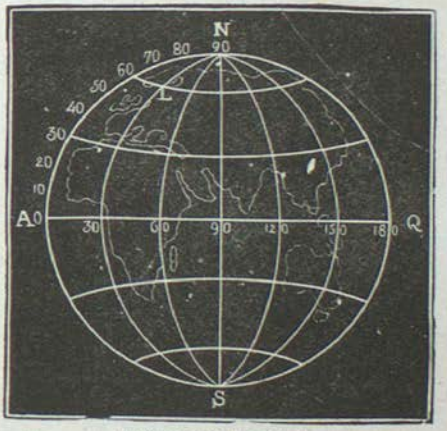
The motion of the earth is known to most people,



Evidence of the spherical form of the earth.

though as everything upon the globe passes with it, and a relative fixity is apparent, this is, of course, not real rest. The earth is moving from west to east at a tremendous rate,—viz., nearly nineteen miles a second! We think a train at sixty miles an hour a fast train; but what should we think of an express going more than 68,000 miles an hour! Yet this is about the rate at which our globe whirls around the sun. Her fastest pace is really 18·5 miles a second; the least about one mile per second less.

That is one motion of the earth ; the other is its motion on its axis. If we send a skittle ball rolling we perceive it turns round as it proceeds. So the earth rotates on its axis, N S, in the accompanying diagram ; the extremities of the axis are called the *poles*. The line in the middle is the equator, which is divided into 360 equal parts, each being $69\frac{1}{10}$ miles in length ; so there are 180 lines, or rings, drawn upon the globe from N to S, and these are *meridians*. In England the degrees are calculated from the Greenwich meridian. We can thus obtain



Latitude and Longitude.

the distance of localities east or west, as we may briefly show.

The distance of any meridian from the first meridian is termed the *longitude*, and it is employed in describing the situation of a place on the earth's surface. Suppose L (in accompanying illustration) a city, its longitude will be 30°, since it lies on a meridian which is 30° from the first. So, for example, the longitude of Oporto is 8° 37′ west, Paris 2 22′ east, Vienna 16° 16′ east, Bagdad 44° 45′ east, reckoned from the meridian of Greenwich, and so on.

At the 180th degree we have proceeded half round the globe, and reached the farthest distance from the first meridian, and are now on the opposite side of the earth, and proceeding in a similar manner in the opposite direction we get west longitude.

It will readily be perceived that a knowledge of the longitude alone is not sufficient to determine the situation of a place on the earth's surface. When we say, for example, that the longitude of a place is 30°, it may lie on any point whatever of the line, N L S, on the whole hemisphere (page 65). This point must therefore be determined more accurately, and hence the first meridian is divided into 90 equal parts north and south of the equator towards the poles. These are called *degrees of latitude*, and the lines drawn through these round the globe, parallel to the equator, are called circles or *parallels of latitude*, and diminish as they approach the poles.

Hence, by the *latitude* of a place we mean its distance from the equator towards the poles, and we speak of north and south latitude according as the place is situated in the northern or southern hemisphere.

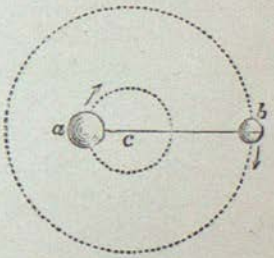
So, for example, the point L (page 65), which has 30° E. longitude and 60° N. latitude is in Sweden.

The latitude is also observable by ascertaining the altitude of the polar star above the horizon when in the northern hemisphere. The longitude is found by the chronometer; for if we know the time at Greenwich we can calculate how far we are east or west of it by seeing whether the local time be an hour (say) earlier or later, and that difference shows we are 15° to the east or the west as the case may be.

The earth's rotation, according to sidereal time, is less than solar time, as we have seen, so we have 365 solar days and 366 sidereal days; so a person going round the world gains or loses a day as he travels east or west

according to his reckoning, as compared with the reckoning of his friends at home. We can easily ascertain the earth's motion by watching the stars rise and set. Now the path in which the earth moves is called an *ellipse*,—very nearly a circle,—but it does not always move at the same rate exactly. We will now look at the relations of the sun and the earth.

Let us take an example. Suppose we have a rod, at each end of which we fix a ball (*see* diagram), and let one ball be three times as large as the other, the common centre of gravity will be at *c*, at one quarter of the distance between the centres, and there the bodies will be in equilibrium. If these masses be set spinning into space they will revolve at that distance from each other, the attraction of gravitation and the force in opposition to it equalizing each other.



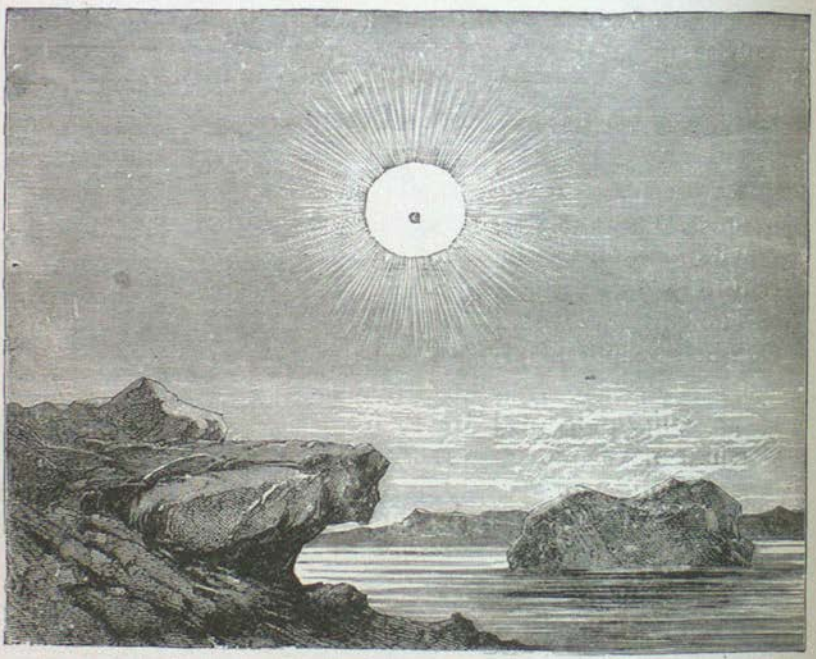
Earth and Sun.

The earth, as we know, proceeds with a tremendous force around the sun, not in a circle, remember, but in an ellipse or oval track, from which it never moves year by year in any appreciable degree. Now what prevents this earth of ours from rushing off by itself into space? Why should not the earth fly away in a direct line? The reason is because the sun holds it back. The force of the sun's gravitation is just sufficient, or we may say so enormously great, that it suffices to retain our globe and all the other planets in their various orbits at the very same distance, and to counteract the force which launches them through space. Therefore, as we have already noticed when considering the sun, it is to that ruler of the day that we are indebted for everything.

What would happen, then, if the earth were suddenly to increase her velocity, or the sun to contract his mass?

—We should be flung into infinite space, and in a short time would be frozen up completely. Our present diurnal course would probably proceed, but all life and existence would cease as we whirled with distant planets through infinity.

Suppose, on the contrary, we were to stop suddenly. We have some of us read that heat is the motion of

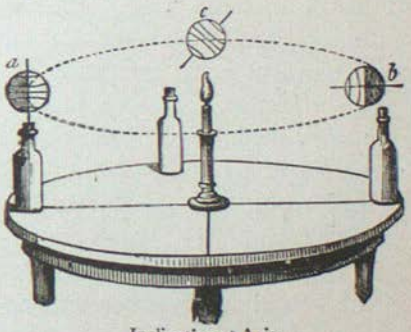


Transit of earth across Sun, seen from Mars.

molecules in ether, and that, when a body strikes another, heat is developed by contact and friction. If the earth were to be stopped suddenly, "an amount of heat would be developed sufficient to raise the temperature of a globe of lead of the same size as the earth 384,000° of the Centigrade thermometer. The greater part, if not the

whole of our planet, would be reduced to vapour, as Professor Tyndall says.

In the diagram (page 52) we shall at once find the explanation of the constantly-recurring seasons, and the amount of our globe which is illuminated by the sun at various times. It will be easily understood that the poles have six months day and six months night. When the earth is at an equinox, one half of the surface is illuminated and the other half in shade, therefore the days and nights are equal. But when the north pole turns more and more towards the sun, the south pole is turning away from it in the same ratio,—the days and nights respectively are getting longer and longer, and at the north and south poles day and night are continuous, for the small spaces round the poles are, during a certain period, wholly in sunshine and shade respectively.



Inclination of Axis.

In March (in the diagram, page 52) we see that exactly one half of the earth is illuminated, and the other is darkened. So in September, when we have the opposite view In June the earth is more inclined apparently to the sun, and more of the surface is exposed to it, so the days are longer in some parts. The opposite effect is visible in December.

The summer heat and winter cold are accounted for by the more or less direct force of the sun's rays, for the more the angle of incidence is inclined the fewer rays reach the object; and if the rays fall at an angle of 60°, the heat is only half what it would be if they came vertically. When the days are shortest the sun is lowest,

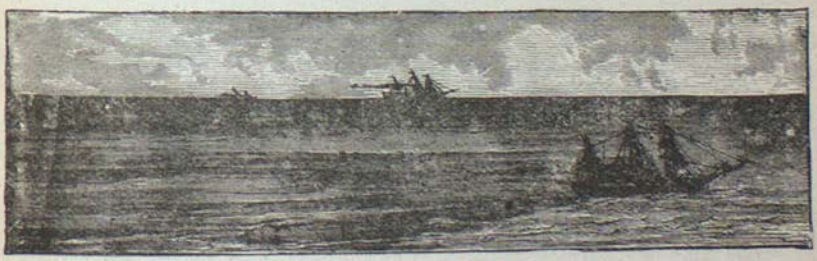
and therefore gives less heat to the earth at certain periods.

The wonderful precision which has adapted the position of the earth on its axis, will be apparent from the illustration (page 69). Here we have a table and some bottles, a candle to represent the sun, and a ball of worsted and a knitting-needle to represent the earth and its axis. Suppose we place the ball in the position at *a*, with its axis perpendicular to the plane of the orbit. As the earth would turn and go round the sun in this supposed case, we should find the days and nights equal, and the sun would quickly scorch up the tropics, and the other portions would have a never-changing spring or winter all the year for ever. This would not be so pleasant, for variety is the charm of nature, and the salt of life. So we may put *a* aside, as the earth would be scarcely habitable under the supposed conditions, and try *b*. Here we find the poles directed to the sun. The whole northern hemisphere would thus be illuminated one half year, and the southern similarly; such rapid changes from heat to cold and back again would not suit us. So we fall back upon *c*, the actual appearance of the position of the earth, and here we find all the most favourable circumstances existing for us. This inclination gives rise to all the varied phenomena of the pleasant gradations of heat and cold, summer and winter, the charming changes of season, and the wonderful results of the ever-recurring days and nights, months and years, as the earth spins round. So we see that the sun does not really rise and set upon the earth; the globe rotates, and brings us into view of the sun, and as we turn we lose his light.

In the foregoing brief description we have learnt some few facts concerning our earth. We have ascertained that the planet we inhabit is round; we have also seen that the earth moves around the sun and around its own axis, and

also that it moves at a tremendous rate; we know that that rate is just counterbalanced by the attraction of gravitation, and the course round the sun gives us varying seasons, day and night. There are many subjects relating to the earth which will be more properly included under Physical Geography. We may here just add the diameter of the earth, and proceed to inquire concerning the moon. The polar diameter of our globe is 7,899 miles; the equitorial diameter 7,925 miles. It is distant from the moon 238,500 miles. We will close this chapter with the letters and characters of the Greek alphabet used in astronomical works to designate the stars.

A α = Alpha	I ι = Iota	P ρ = Rho
B β = Beta	K κ = Kappa	Σ σ = Sigma
Γ γ = Gamma	Λ λ = Lambda	T τ = Tau
Δ δ = Delta	M μ = Mu	Y υ = Upsilon
E ϵ = Epsilon	N ν = Nu	Φ ϕ = Phi
Z ζ = Zeta	Ξ ξ = Xi	X χ = Chi
H η = Eta	O o = Omicron	Ψ ψ = Psi
Θ θ = Theta	Π π = Pi	Ω ω = Omega



A ship disappearing below the horizon.

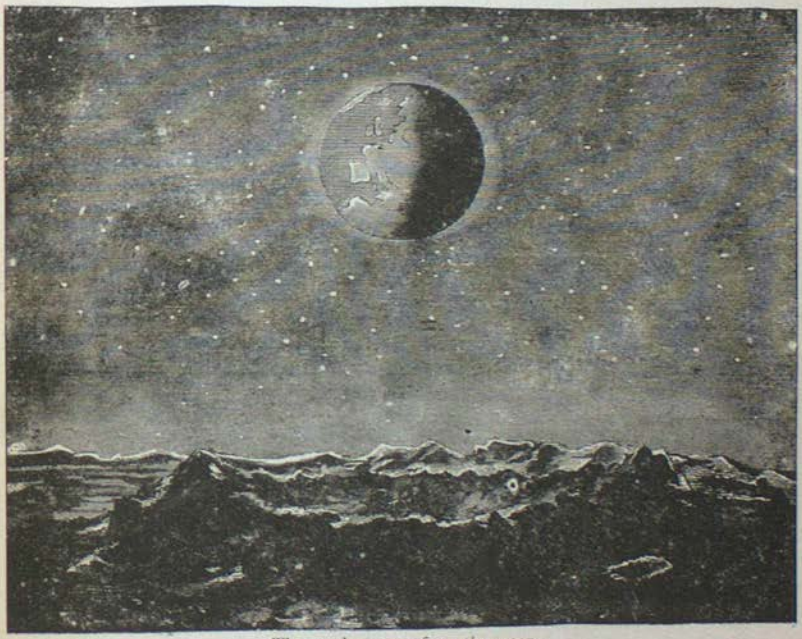
CHAPTER VI.—THE MOON.

WHAT IS IT LIKE?—MOON SUPERSTITIONS—DESCRIPTION OF THE MOON—PHASES—TIDES—ECLIPSES.

FROM the early days of childhood every man and woman has been familiar with the moon. This satellite of earth has been domesticated, so to speak, amongst us; and while the sun and other stars have been glorified in poetic and prose effusions, the moon has been always more tenderly addressed. The soft (reflected) light of our attendant moon is much more attractive than the brilliancy of the greater light "that rules the day." The moon is regarded as our particular property, and has awakened an interest in our minds since the time that we could, as we fancied, see the "Man in the Moon."

In ancient times the moon was supposed to possess some light of her own, and to be inhabited by immense creatures, and various theories continued to be promulgated respecting her, until the telescope came into use, and then astronomers began to find out many new things concerning Luna. Now, what has the telescope told us regarding our moon?—It shows us that there are mountains and craters, and numerous traces of volcanic action. At one time it was supposed that the dark masses apparent in the surface of the moon, and which can easily be distinguished by the naked eye, were seas, and maps of the moon were made, marking continents and craters.

If it were possible to reach the moon, as M. Jules Verne's travellers did, we should find a very irregular and corrugated surface—plains and mountains without water. We should be able to see the stars in the daytime, because there is no atmosphere around the moon, and there is a silence that "might be felt." The appearance of our earth from the moon, and the beauty of the stars in



The earth as seen from the moon.

the unclouded and waterless space around the satellite, must be very grand, and has been, in a measure, depicted in the illustration above.

From the illustration on page 75 we gain some idea of what the moon is like. We see the rugged and cratered appearance of the disc; it is a desert waste, so far as we can ascertain, without inhabitants, and, in all probability, with-

out vegetation. For there being no moisture amongst the plains and craters and mountains of our satellite, we must conclude that the moon is dead. It is a very interesting, —nay, a fascinating study. When we take up our telescope and look from the window at the heavens the most beautiful object within our small telescopic vision is the moon shining like a silver plate, and we wonder what is up there. With a small telescope even we can discern many interesting features in the moon at the full, which will assist us in verifying the diagrams in books and their explanations.



The Moon : the ring plain Copernicus.

As the moon is only a few miles away, comparatively speaking, and as the large telescopes now in use bring us within a measurable distance of the surface, we are enabled to speak more positively about our changeable satellite than of any of the planets. When we look steadily at the full moon we perceive upon its surface dark and light tracts called "seas," though they are dried up now. Thus we hear of the "Sea of Serenity," the "Sea of Storms," and the "Sea of Tranquillity"; and in the map upon a subsequent page you may see the names of the seas,

mountains, and the general formations of the surface of the moon. Maps of the moon are now to be procured, though no personal visits can be made to the satellite. It is very interesting to observe or to read about the structure of the moon, for we may thus learn how similar the earth and her attendant are in formation; but one important agency—that of water—has made a considerable difference in the *appearance* of the formations. In the moon we have mountains, plains, and rugged craters; the surface is not



Telescopic appearance of the Moon.

level, because the sunlight is visible sooner at some points than others. The chief mountain chain is the Apennines, and has a great elevation; many traces of volcanic agency are discoverable amid the great desolation; and awful silence reigns throughout.

As is well known, water has a great erosive power, and its action disintegrates the surface of the earth with rapid persistency. So the physical appearance of the globe has become much changed in the course of ages: ravines

exist where plains used to extend, and rivers cut their way through deep gorges to the sea. The sands and other deposits are overlaid, and thus the whole outward appearance has been altered. Not so the moon. With a very attenuated atmosphere without clouds or rain, there is no moisture, no lake, no water in the moon now. What may have been we can only conjecture. If there ever were lakes or seas, they have all been long ago absorbed.



Formations near Mostig. Low power.

The heat upon one side of the moon must be very great at one period, and the cold on the opposite side intense, as one would think—yet upon this fact authorities differ somewhat. If the moon possess no atmosphere of *any kind* it would be fearfully cold and extremely hot at intervals, but a surrounding medium, even of very little density, would modify the extremes; and while we must accept the fact that the temperature varies very much we need not place it above 100° of heat, nor below 20° of cold. So from close observation and comparison we are enabled to form a very fair opinion of the "past" of the moon, and to ascertain that the same forces of nature which have moulded the planet we inhabit, have been at work in the moon also. When we study "Selenography," therefore, we shall find a record of a history which may some day bear a parallel to the history of our physical world.



The ring-plain Copernicus, as seen with small magnifying power.

The moon, as all are aware, moves round the earth attendant upon us, but entirely under the control of the sun; our satellite, moreover, has been the subject of many

superstitions. A great many rites and even domestic actions—such as the killing of fowls—were regulated by the moon ; and in Scotland, Scandinavia, and other portions of Europe she has always been regarded as effecting destiny. There are many interesting myths connected with the moon, and indeed with astronomy generally, and from a volume entitled "Notes on Unnatural History," some very amusing extracts might be made. It will not be out of place to mention a few of these myths.



The walled-plain Plato.

The Chinese have an idea that a rabbit exists in the moon, and is the cause of the shadows we see. The Buddhists think a holy hare is up there. In the Pacific Islands there is a belief of a woman in the moon ; she was sent there because she wished her child to have a bit of it to eat ; and Mr. Buchanan has versified the old Scandinavian myth about the two children kidnapped by the moon as they returned from a well with a bucket of water slung upon a pole. The Jews placed Jacob in the moon, and the Italians say that Cain inhabits the luminary with



Map of Moon showing principal formations.

A Mare Crisium.
B Palus Somnii.
C Mare Serenitatis.
D Mare Tranquillitatis.
E Mare Fœcunditatis.
F Mare Nectaris.
G Sinus Medii.
H Mare Vaporum.
I Lacus Mortis.
J Mare Frigoris.
K Mare Imbrium.
L Oceanus Procellarum
M Mare Humorum.
N Mare Nubium
O Sinus Iridum.

a Apennine Mts.
b Caucasus.
c Carpathians
d Pyrenees.
e Altai Mts.
f Riphaen Mts.
g Doerfel Mts.
h Leibnitz Mts.
i Corderillas.
j D'Alembert Mts.
k Taurus Mts.
l Hæmus Mts.
m Alps.

1 Clavius.
2 Maginus.
3 Maurolycus.
4 Stöfler.
5 Tycho.
6 Longomontanus.
7 Wilhelm I.
8 Schiller.
9 Schickhardt.
10 Hainzel.
11 Furnerius.
12 Metius.
13 Fabricius.
14 Riccius.
15 Piccolomini.
16 Zagut.
17 Apianus.
18 Walter.
19 Hell.
20 Pitatus.
21 Hesiodus.
22 Capuanus.
23 Ramsden.
24 Vieta.
25 Petavius.
26 Vendelinus.
27 Langrenus.
28 Fracastorius.
29 Theophilus.
30 Cyrillus.
31 Catharina.
32 Sacrobosco.
33 Almanon.
34 Albufeda.
35 Albategnius.
36 Hipparchus.
37 Ptolemy.
38 Alphonsus.
39 Purbach.
40 Regiomontanus.
41 Thebit.
42 Arzachel.
43 Bullialdus.
44 Lalande.
45 Mösting.
46 Herschel.
47 Gassendi.
48 Mersenius.
49 Sirsalis.
50 Grimaldi.
51 Riccioli.
52 Hevelius.
53 Condorcet.
54 Taruntius.
55 Proclus.
56 Cleomedes.
57 Romer.
58 Posidonius.
59 Plinius.
60 Julius Cæsar.
61 Manilius.
62 Godin.
63 Agrippa.
64 Triesnecker.
65 Bode.
66 Gambart.
67 Eratosthenes.
68 Copernicus.
69 Reinhold.
70 Landsberg.
71 Encke.
72 Kepler.
73 Marius.
74 Archimedes.
75 Timocharis.
76 Euler.
77 Aristarchus.
78 Herodotus.
79 Struve.
80 Messala.
81 Mare Humboldtanius.
82 Atlas.
83 Hercules.
84 Endymion.
85 Eudoxus.
86 Aristoteles
87 Linne.
88 Autolycus
89 Aristillus.
90 Cassini.
91 Plato.
92 Helicon.
93 Pythagoras.

a dog and a thorn bush. In the *Inferno* of Dante this is referred to, and we know that in *A Midsummer Night's Dream* we have the moon coming out to shine upon the loves of Pyramus and Thisbe with the dog and the thorn-bush; and in the *Tempest* the same idea is mentioned by Caliban. Readers of Longfellow will recall the lines how "the good Nokomis answered" Hiawatha, who asked about the moon—

> "Once a warrior, very angry,
> Seized his grandmother, and threw her
> Up into the sky at midnight.
> Right against the moon he threw her,
> 'Tis her body that you see there."

But modern scientific research has exploded all these charming old myths, and laid bare the facts for us. We must now resume.

The moon moves around us in $27^d\ 7^h\ 43^m\ 11{\cdot}461^s$. Its diameter is about 2,160 miles, and it is much less dense than our earth, and so the force of gravity is less there than here. Its mean distance from us is 238,833 miles. The moon goes through certain changes or phases every twenty-nine days or so; and while rotating on its own axis our satellite goes round the earth, so that we only see one side of the moon, inasmuch as the two motions occupy almost exactly the same space of time. So we generally see the same space of the moon, though there is a slight variation at times. This movement or swaying of the central point is called the moon's "libration," and is an optical effect, due to the inequalities in the motion of the moon in its orbit, and to the inclination of its equator and orbit to the ecliptic.

We have given a map of the moon, on which the mountains, seas, and craters can be perceived, according to the list. The hill ranges extend for hundreds of miles, and the elevation reaches 30,000 feet, and even more in places.

The so-called craters do not resemble volcanoes when viewed closely, but take the form of basins or valleys surrounded by lofty hills. One great plain called Copernicus is more than fifty miles across. Respecting the appearance of the moon let us quote Mr. Lockyer.

"Fancy a world without water, and therefore without ice, cloud, rain, snow; without rivers or streams, and there-

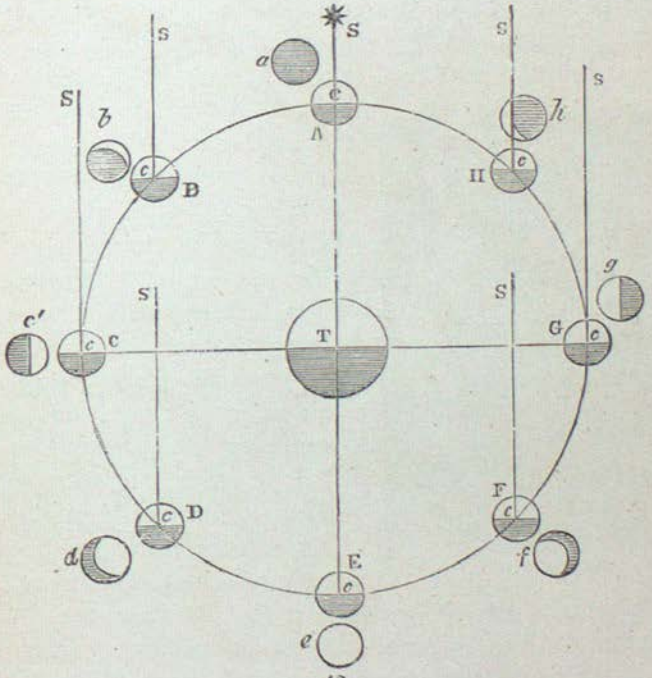


The Apennines and walled plain Archimedes.

fore without vegetation to support animal life;—a world without twilight or any gradations between the fiercest sunshine and the blackest night; a world also without sound, for as sound is carried by the air, the highest mountain on the airless moon might be riven by an earthquake inaudibly."

Phases of the Moon.

We have said that the moon revolves around the earth in the same time as she turns upon her own axis, and always presents one side to us when she appears. Any one can ascertain this by putting a candle upon a round table, and walk round it facing the candle. The experi-



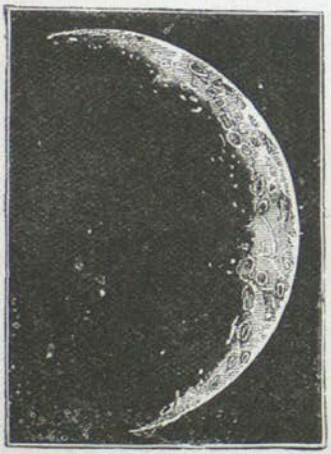
43.
Phases of the Moon.

mentalist will find that he will turn upon his own axis as well as turn around the table. Thus we shall see how the moon changes, for to be as changeable as the moon is proverbial. These different aspects or phases we shall now proceedto explain.

The time intervening between one "new" moon and

another is 29^d, 12^h, 44^m, 2^s, and is termed a synodic revolution. This is longer than the sidereal revolution, because the earth is also moving in the same direction, and the moon has to make up the time the earth has got on in front, as it were. So the moon travels nearly thirteen times round the earth while the latter is going round the sun.

The revolutions of the moon have been a measurement of time for ages, and her varying appearances during lunation are always observed with interest. The illustration (page 81) will assist us materially. The sun's rays fall in a parallel direction upon the earth and moon, and let us suppose that S is the sun in the diagram and T the earth; C at the various points is the moon, the capital letters, A, B, C, etc., indicating the planet as she appears from the sun, and the small letters show how she appears to us from the earth.



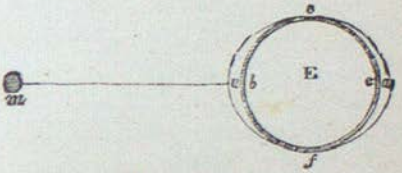
Crescent Moon.

Let us suppose that the sun, earth, and moon are in conjunction—or in a direct line. The phases, C and G, are the moon's "quadratures." At A we see the sun shining on the moon, but we only have the dark side. It is then "new" moon; but by degrees, as she goes round in her orbit, we perceive a small crescent-shaped portion, lighted up by the sun at B and *b*. At *c* we have the first quarter or half-moon. When she is in opposition she is at full moon, and so on to the last quarter and conjunction again.

The moon's phases may be easily shown by means of a medium-sized lamp to represent the earth, a smaller one

to serve as moon, and a light to act as sun all at the same height. Colour the "lunar" globe white, and if we move it about the "earth" globe, we shall see the various phases of the moon in the sharp shadows.

THE TIDES.



Moon's attraction.

The ebb and flow of our tidal waters depend upon the moon to a great extent. The phenomenon is so common, that we need only refer to it, but the cause of the tides may be stated. Twice every day we have the tides twelve hours apart, and the flow and ebb are merely examples of the attraction of gravitation, which is exercised upon all bodies, either liquid or solid. The tides are highest at the equator and lowest at the poles, because the tropics are more exposed to the influence of the lunar attraction.


New Moon.

By the small diagram we shall be able to see in a moment how the moon acts. The moon being nearer to the earth at *b*, the water will be naturally attracted to the ball, *m*, and cause high water (*a*); and a similar effect will be produced opposite, because the earth is attracted, so the waves are higher than the ground which has been attracted away from the water, and the waters will flow in and cause a high tide at *d*, but not *so* high a tide as at the opposite point, *a*. It can then be understood that there will be low water at the other two sides, *e* and *f*, because the water

has been taken away, so to speak, for the high tides at *a* and *d*. We shall learn more of this under Physical Geography.

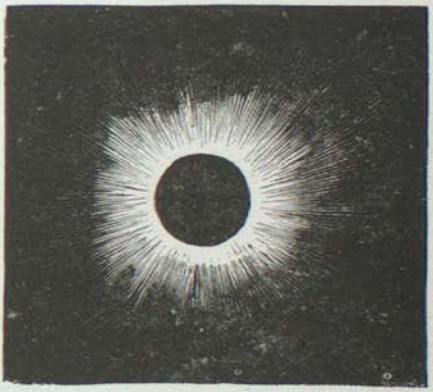
The moon revolves round the earth in a changeable elliptical orbit, intersecting the ecliptic at certain points called *Nodes*. When the moon is nearest to the Earth she is said to be in *perigee*, when farthest from us she is in *apogee* (the line uniting these points is the line of *apsides*), the difference in distance being about 4,000 miles. She passes the sun periodically, and so if the moon moved in the plane of the ecliptic there would be eclipses of the sun and moon twice a month ; but as the orbit is inclined a little, she escapes by moving north or south. We will now endeavour to explain this theory.

ECLIPSES.

We have briefly considered the SUN and EARTH and the MOON separately. We are now about to regard the effects produced by them when they come in each other's way and cause ECLIPSES, which are observed with so much interest. There are eclipses of the sun and of the moon. The former occur at the time of new moon, and the latter at full moon ; and this will be at once understood when we remember that the sun is eclipsed by the moon passing between us and the sun ; and the moon is eclipsed because the *shadow of the earth* falls upon her when she is *opposite* the sun, and therefore "full."

Readers of the voyages of Columbus will remember that he managed to obtain supplies from negatively hostile Jamaica savages by pretending to cause an eclipse of the moon, which he knew was about to take place, and to the ancients eclipses were of dire portent. Even in enlightened Rome, to ascribe an eclipse to the causes of nature was a crime. The Chinese have an idea that great dragons are devouring the moon when she is eclipsed.

There are total, partial, and annular eclipses. The former terms speak for themselves; the latter name is derived from "annulus," a ring; for a ring of light is left around the dark portion eclipsed, and is only seen in solar eclipses. In one sense the eclipse of the sun is really an eclipse of the earth, because it is caused by the shadow of the moon falling upon the earth.



Solar eclipse with corona.

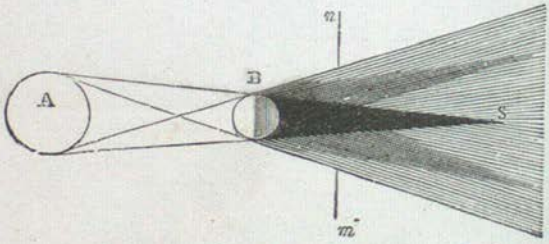
If a bright body, A, be larger than the dark body, B, there will be two kinds of shadows—viz., the *umbra* and the *penumbra*. For instance, the umbra is the central dark part in the cut below, and the penumbra is the lighter portion. As soon as the eye is placed on the umbra, it can perceive no part of the source of light, A, which appears to be eclipsed. On the other hand, the *penumbra* originates in that locality where only a portion of the light proceeding from a luminous object can fall; hence an eye in the *penumbra* would see a part, but not the whole of the illuminating body. This shadow also forms a cone, the apex of which, if extended, will fall before the opaque body. If we receive the shadows so projected at *m n*, for example, on a white sheet, we have in the centre a dark circle, which is the umbra, surrounded by the penumbra, which gradually decreases in intensity towards the exterior (*see* page 86). The farther we hold the sheet from the body producing the shadow, the umbra decreases, and the penumbra is



Umbra and penumbra.

enlarged. For where (in solar eclipses) the *umbra* falls there is totality; within the penumbra partial eclipse only.

Lunar Eclipse.—Let A be the sun, and B the earth, the length of the umbra of the latter will exceed 108 diameters of the earth. Since the moon is only about thirty terrestrial diameters distant from the earth, and as the diameter of the earth's shadow, at this distance, is nearly three times as large as the apparent diameter of the moon, it follows that when the latter enters this shadow, she must be totally eclipsed, for at those places where the moon's shadow falls there is total eclipse. If the moon's orbit were coincident with the ecliptic, or if both moon and earth moved round



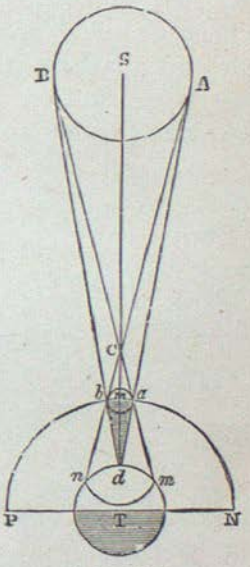
Lunar eclipse.

the sun in the same plane, there would be an eclipse at every conjunction, and at every opposition,—*i.e.*, a solar eclipse would happen at every new moon, and a lunar eclipse at every full moon. But we have seen that the lunar orbit cuts the ecliptic only in two points; consequently an eclipse of the moon is possible only when, at the time of opposition, the moon is in one of her nodes, or in close proximity to it, which can only occur twenty-nine times in the space of eighteen years.

A lunar eclipse begins on the eastern margin of the moon, and is either *total*, when her whole disc enters the umbra, or *partial*, when only part of her disc is in the shadow. A total eclipse may last for two hours.

We shall understand this better, perhaps, with the diagrams.

Solar Eclipses.—When the moon and the sun are in conjunction, the moon's place may be represented by M, between the earth, T, and the sun, S. If this conjunction occur when the moon is in one of her nodes, or within 16° of it, the shadow of the moon will fall upon the earth, and the sun will be eclipsed. At other places the sun will not be entirely covered ; and if the moon be moved farther off, so that its shadow will not reach the earth, and so not cover the sun up completely, we shall have an annular eclipse, because a rim of the sun will be visible.



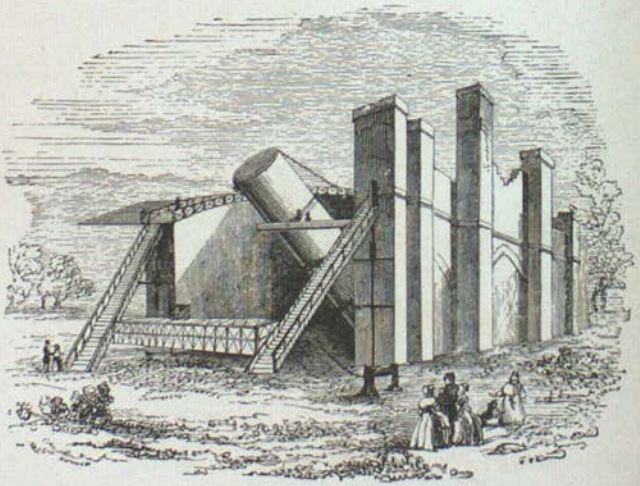
Solar eclipse.

The lunar umbra extends from the moon by a space about equal to her distance from the earth, and hence only a small portion, *d*, of the earth's surface enters the lunar umbra. To the inhabitants of this part of the earth the sun will be totally eclipsed, and the eclipse will be annular if only the margin of the sun's disc remain uneclipsed by the lunar shadow. This is only possible when the moon is in her apogee, or greatest distance from the earth, where her apparent diameter is less than that of the sun, which it cannot in general exceed more than 1′ 38″. Hence the duration of a total eclipse of the sun cannot be more than 3¼ minutes.

On the contrary, the penumbra of the moon is diffused over a much larger portion, *n m*, of the surface of the earth, since its section is five-ninths of the earth's diameter. The inhabitants of this portion of the earth do not receive

light from all parts of the sun, consequently a *part* of this luminary is invisible to them, and the eclipse is said to be *partial.*

Solar eclipses commence on the western margin of the sun, and advance to the eastern. On account of the proximity of the moon to us, an eclipse of the sun is, in all places above the horizon of which the sun appears, visible neither at the same time, nor is it of equal duration, nor of equal extent : in some parts it may not be visible at all. In favourable situations, the diameter of the umbra, where it reaches the earth, amounts to about 167 miles, and on this small strip of the earth's surface only can the sun appear totally eclipsed.

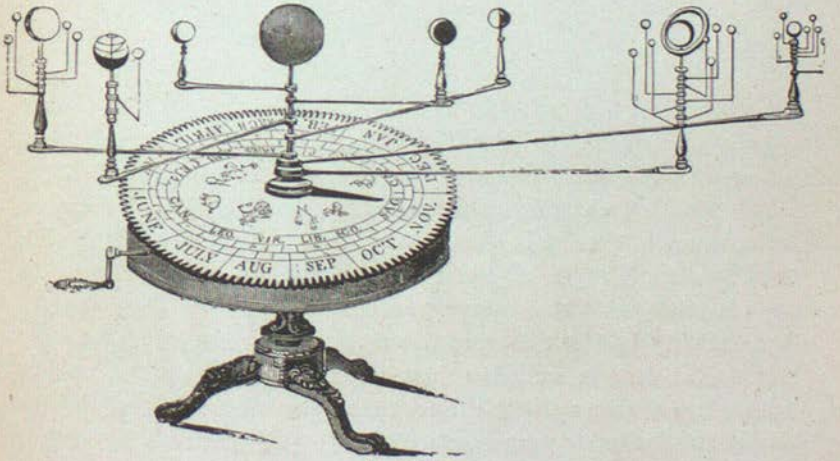


Lord Rosse's monster telescope.

CHAPTER VII.—THE PLANETS AND ASTEROIDS.

MERCURY.

INCLUDING our own globe there are eight principal planets—viz., Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. The two first-named being between us and the sun, are termed *interior* planets ; the others are *exterior*. Mer-



An Orrery.

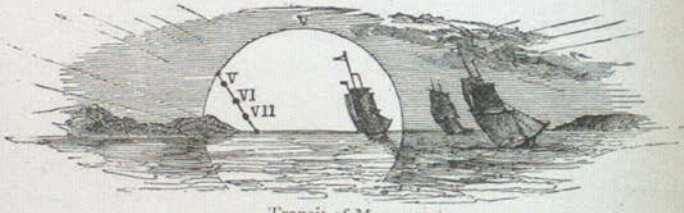
cury, Venus, and Mars are smaller than Earth. The other four are much larger.

We have already described the planets as bodies wandering through the zodiac, and reflecting the sun's light.

Their orbits are very different from the moon's; for instance, planets take a retrograde motion as well as a direct one. The sun and the planets revolving around him constitute the solar system.

We will commence our brief consideration of them with Mercury, the planet nearest to the sun.

The distance of Mercury from the sun is 35,000,000 of miles, less than half the distance our earth is from him, and so receives much more heat and light than we do. The sun to the Mercurians, if there be any inhabitants upon the planet, must appear about seven times larger than he does to us. Mercury's year is about eighty-five



Transit of Mercury.

days in length, so the seasons must be shorter if they follow the same rotation as ours. It passes through space with an exceedingly rapid motion, and so probably the ancients called the swift planet Mercury after the winged messenger of Jove.

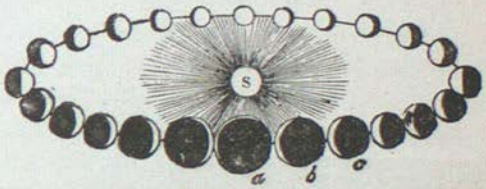
Mercury is not an easy planet to observe, owing to its proximity to the sun, yet the ancients managed to descry it. But it can be seen just before sunrise and sunset in autumn, and in spring if the weather be clear. It possesses phases similar to our moon. Some authorities have stated that Mercury has an atmosphere, but this circumstance, as well as its formation, is still shrouded in mystery. Mercury's day is a few minutes longer than ours.

A transit of Mercury is represented in the above illustration. This phenomenon took place in 1845, but

there have been many others noticed. The first recorded took place in November 1631, and these transits always occur in May or November.

VENUS.

VENUS is the planet next in order, and revolves about 66,000,000 of miles from the sun. It is the nearest planet to the earth, and is somewhat smaller than the latter. This planet is both a morning and evening star, and is very brilliant—so much so, that any close observation with the telesope is not possible ; and when at her nearest point she is invisible as she passes between us and the sun, and of course when fully illuminated she is directly beyond the sun, and enclosed in his rays. But under other circumstances she is distinctly visible as a crescent in the evening, and nearly full as a morning star. Venus goes round the sun in 224 days, and her day is rather less than ours.



Orbit of Venus.


Venus, at quadrature.

Venus has long been celebrated as the morning and evening star, as "Lucifer" and "Hesperus." "Lucifer, son of the morning," is mentioned by Isaiah. That Venus possesses an atmosphere denser than our own can scarcely be doubted. The observations made during the successive transits, particularly the last (1874), seem to have established the fact that aqueous vapour exists around, and water in, Venus. No satellite

can be found, though the ancients reported such an attendant upon this planet.

The apparent diameter of Venus varies considerably in consequence of her varying distances at the inferior and superior conjunction. When nearest the earth, if she presented her fully illuminated disc to our gaze, we should see a miniature moon, and even under the circumstances Venus throws a shadow, so brilliant is her light.

The transits of Venus have been referred to, and, like those of Mercury, are simply a passing, or "transit," of the planet across the illuminated disc of the sun. The transits afford means to ascertain the volume and distance, etc., of the sun, and this year (1882) the next transit is expected. There will not be another for more than one hundred years.



Venus, near inferior conjunction.

Whether Venus has a constitution similar to our globe is of course doubtful. The matter is less dense than the earth, and there is an atmosphere half as dense again as ours. Spots have been noticed crossing the planet, which may have been vapours or clouds, and the rotation of Venus on its axis was calculated from these spots as being $23^h\ 21^m\ 22^s$. The seasons in Venus must be very different from ours, as her inclination is greater than our earth, and as the sun is so much nearer to her than to us her tropical and polar regions are close, and a vertical sun is scarcely enjoyed by two places for three successive days, and she may have two winters and summers, two springs and autumns!

MARS.

Having already considered the earth, we pass on from Venus to Mars. The orbit of the latter planet is exterior to the earth's, as is proved by his never appearing "horned," nor ever passing across the sun's disc. Therefore no "transits" of Mars can take place as transits of Venus and Mercury.

Yet Mars is most favourably situated for astronomical observation by us, because it turns its full disc to us. Venus is nearer to us than Mars—but, as we have explained, when she comes nearest to us she is quite invisible. Astronomers have been enabled to ascertain a good deal concerning the planet of war—"the red planet Mars."



Mars seen from the earth.

Mars has been considered very like the earth. We perceive seas and continents, and the shape of Mars is like the earth. But our globe is larger than Mars, which is much less dense, so the force of gravitation is less also. Mars moves upon his axis in about twenty-four hours and a half, and takes rather more than 686 days to revolve round the sun. (*See* page 38.) Thus its days are a little longer than, and its years twice as long as our days and years. When in "opposition," or on the opposite side to us from the sun, Mars is at his brightest. This happened in September 1877. He will come close again to us in 1892.

All planets are wanderers, but of all the wanderers Mars

has the most eccentric orbit. He curls about, so to speak, in loops and curves in a very irregular manner, and therefore his distance from the earth varies very considerably; and this eccentric behaviour of the warlike planet must have, as we believe it did, puzzled the ancients very much. But—and here reason came to human aid—this very fact, this great eccentricity of the planetary motions, caused Copernicus to investigate the subject with great attention, and he at length explained the true reason of these irregular orbits from the hypothesis that it was around the sun, and not around the earth that the planets moved in regular orbits.



Earth seen from Mars.

It is quite ascertained that Mars is very like our earth in miniature. We annex a diagram of the planet, and when it is examined with a good telescope the seas and continents can be quite distinctly perceived. At the poles there appears to be a white or snowy region at varying periods, which would lead us to the conclusion that the atmospheric changes and the seasons are similar to our own; and as the inclination of the planet is nearly the same as the earth, this supposition may be accepted as a fact.

Thus we see that Mars is the most like earth of all the planets, and its inhabitants—if, indeed, it is now inhabited—must have a beautiful view of us when the weather is fine, for we are so much larger. Mars is also attended by two satellites, or moons, as Professor Hall reported from Washington in 1877. These moons have been named

Deimos and *Phobos*, and are both very small, their diameter being only about six miles; but late astronomers have reasoned that they must be three times this diameter.

There have been numerous theories concerning Mars being inhabited, and of course these suggestions made respecting life on one planet may, with varying circumstances, be applied to another. Each planet may have had, or may yet have, to pass through what has been termed a "life-bearing stage." We on earth are at present in the enjoyment of that stage. So far as we can tell, therefore, Mars may be inhabited now, as he bears much the same appearance as our planet. Certain changes are going on in Mars, and all planets, just as they go on here in our earth, and as they did long, long ages before the earth was populated, and which will continue to go on after life on the earth has ceased to exist.

Mars is, as we know, much further away from the sun than earth is, and must receive less direct heat. When he was created, or formed, we can only conjecture, but in all probability he cooled before the earth did, as he is smaller. Here another theory concerning the state of Mars arises, and in support of it we may quote an American authority upon the planet.

"His mass is not much more than one-ninth of the earth's, while his surface is about one-third of hers. Then, if originally formed of the same temperature, he had only one-ninth her amount of heat to distribute. If he had radiated it away at one-ninth of her rate, his supply would have lasted as long, but radiation takes place from the surface in proportion to the surface, hence he parted with it three times as fast as he should have done to cool at the same rate as the earth, and must have attained a condition which she will not attain until three times as long an interval has elapsed from the era of her first existence than has already elapsed. Geologists agree that the

last-named period must be measured by many millions of years; hence it follows that twice as many millions of years must elapse before our earth will be in the same condition as Mars, and Mars must be three times as far on the way toward planetary decrepitude and death as our earth. Then assigning two hundred thousand years as the extreme duration of the period during which men capable of studying the problems of the universe have existed, and will exist on this earth, the theory holds that Mars would have entered on that stage of his existence many millions of years ago, and that the appearance of the planet itself implies a much later stage of planetary existence."

Mars is a very interesting study, and the reddish hue which is so distinctive is perceived in certain spots when examined by the telescope's aid. These red places were discovered by Cassini. Mr. Dawes made drawings of Mars, and Mr. Proctor has by their aid constructed a regular map of Mars, and a chart of the surface of the planet. There is much more land than water on Mars, as the bright surfaces which indicate land are much more extensive than the darker portions which betoken the existence of water. But these "markings" are not always visible, in consequence of something coming between us and the land on Mars, and this has been attributed to the production of vegetation, which a French *savant* declared was ruddy-coloured, and that this autumnal tint departed in the winter.

The seasons of Mars are not equal, in consequence of his wandering propensities, and winter is warmer up there than our winter, while summer is cooler than our summer. That there are clouds and an aqueous atmosphere surrounding Mars we learn from spectroscopic observation and analysis, and in fine we may look upon Mars as similar to our earth. Respecting the question of its

habitation we take the liberty to quote Mr. Richard Proctor :—

"I fear my own conclusion about Mars is that his present condition is very desolate. I look on the ruddiness of tint to which I have referred as one of the signs that the planet of war has long since passed its prime. There are lands and seas in Mars, the vapour of water is present in his air, clouds form, rains and snows fall upon his surface, and doubtless brooks and rivers irrigate his soil, and carry down the moisture collected on his wide con-

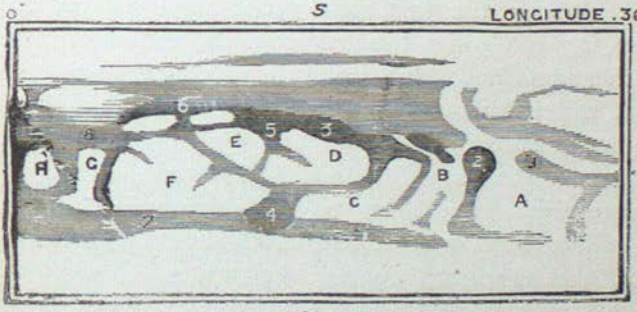


CHART OF MARS (Names according to Proctor and Green).

A Beer Continent.
B Herschel Continent.
C Fontana Land.
D Secchi Continent, East.
E Secchi Continent, Central
F Secchi Continent, West.
G Mädler Continent.
H Leverrier Land.
1 Herschel Strait.
2 Dawes Ocean.
3 Maraldi Sea.
4 Oudemans Sea.
5 Trouvelot Bay.
6 Funchal Bay.
7 Campani Sea.
8 De la Rue Ocean.

tinents to the seas whence the clouds had originally been formed But I do not think there is much vegetation on Mars, or that many living creatures of the higher types of Martian life as it once existed still remain. All that is known about the planet tends to show that the time when it attained that stage of planetary existence through which our earth is now passing must be set millions of years, perhaps hundreds of millions of years ago. He has not yet, indeed, reached that airless and waterless condition, that extremity of internal cold, or in

fact that utter unfitness to support any kind of life, which would seem to prevail in the moon. The planet of war in some respects resembles a desolate battle-field, and I fancy that there is not a single region of the earth now inhabited by man which is not infinitely more comfortable as an abode of life than the most favoured regions of Mars at the present time would be for creatures like ourselves."

The Moons of Mars.

We must devote a few lines to the satellites of Mars, which during the last four years have proved a very interesting study for the astronomers, and some very interesting facts have been ascertained concerning the ruddy planet, which is now proved not to be "moonless Mars," as the poet declared.

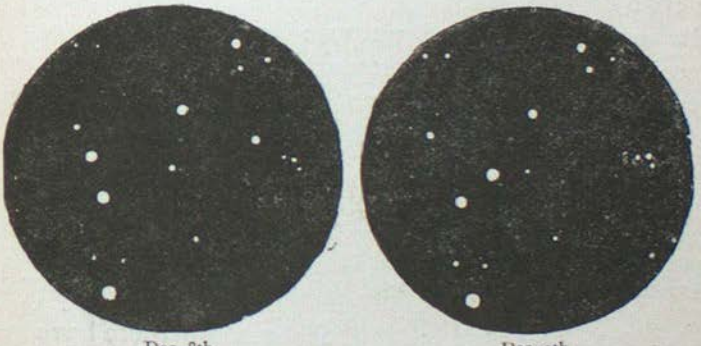
There are two satellites, which, in consequence of their distance from him, being so different, vary in apparent size. The outer one is twelve thousand, the inner one about three thousand five hundred miles from the planet, so the former would revolve in about thirty hours in a direction from west to east, and the inner moon goes round in the same way in about seven hours and a half. Mars revolves in twenty-four and a half hours from west to east. So the outer moon rises for him in the east, and the inner one in the west. This is accounted for by the fact that one travelling slower than Mars rises in the east, the other outruns him, and comes up in the west.

But if we suppose ourselves upon Mars we shall find that, after all, we have only one moon properly so called. The outer satellite is very small and very far away, so it is useless to give light—at most, it is no bigger than Mars appears to us on earth. So the Martians do not see two moons passing each other in the sky—that is, unless their eyes are of greater range and power than ours. Thus they have one moon rising in the west, appearing in all its

phases *every night*, while our moon takes twenty-eight days to pass through her phases; for we must remember that Mars' moon takes only seven hours and forty minutes to pass through its orbit, and therefore each quarter will not occupy quite two hours.

The Minor Planets, or Asteroids.

Passing onward from Mars towards Jupiter we arrive at a number of smaller planets, which will not concern us very much, as they are very small and scarcely visible without a good telescope. But a very interesting chapter in the history of astronomy was commenced when the



Dec. 8th. Dec. 9th.
Field of view showing motion of minor planets amongst the stars.

discovery of these bodies was begun. In old times astronomers noticed a very considerable gap between Mars and Jupiter, which was remarkable when the regular progression of the distances between the planets was remembered. So Kepler was of opinion that some planet would be discovered having its orbit in that space between Mars and Jupiter. It is, however, to Piazzi, the Italian, that the discovery of the zone of asteroids is due.

Piazzi was surveying the constellation Taurus, where he fancied he had discovered a change of place in a star which he had observed on the 1st of January in that year

(1801). He was quite sure of this change next day (the 3rd of January), and he expressed his opinion to Bode and Oriani. But letters took a long time to pass in those days, and when the other astronomers had received the advices the new star had been lost in the sun's glory. But after a year, on the 31st December, 1801, the planet was again seen and the discovery was proved. The new planet was named CERES.

The discovery of Ceres led to other discoveries. For, while searching for her, Olbers found other minor planets, and so on to the present day. Now we have nearly two hundred asteroids, and more are probably to be found in the zone beyond Mars.

It would answer no purpose to give a list of the asteroids. We need only remark that the first four were discovered in quick succession, and then a lapse of thirty-eight years occurred before the fifth was found, thus—

CERES,	discovered by	Piazzi at Palermo, January 1st, 1801.
PALLAS,	„	Olbers at Bremen, March 28th, 1802.
JUNO,	„	Harding at Lillienthal, September 2nd, 1804.
VESTA,	„	Olbers at Bremen, March 20th, 1807.
ASTRÆA	„	Hencke at Driessen, December 8th, 1845.

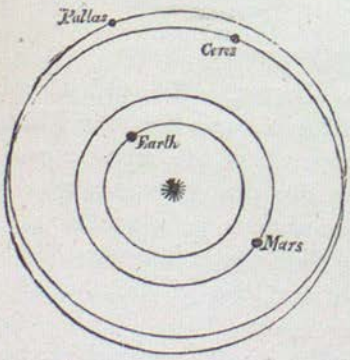


Fig. 585.—Orbit of asteroids.

Since 1848 there have been numerous minor planets discovered every year.

The hypothesis that all these asteroids are fragments of one large planet which has been destroyed was started by Olbers; and in confirmation of this view it has been determined that the asteroids have essentially the same character. The orbits of these minor planets are different from the larger "wanderers," and

cross each other, as will be seen from the diagram on page 100, so that a collision may one day ensue.

Planetoids and extra zodiacal planets are titles which have been bestowed upon these bodies, of which VESTA is the first in order in the system, and revolves in 1,325 days, at a mean distance of 225,000,000 of miles from the sun. JUNO and CERES take each about four of our years to revolve in their orbits, at greater distances still, averaging 260,000,000 of miles. Pallas and Ceres are most alike in their periods and distance from the sun; the principal asteroids are only about 300 miles in diameter, while the smaller are very tiny indeed, and one certainly has quite disappeared.

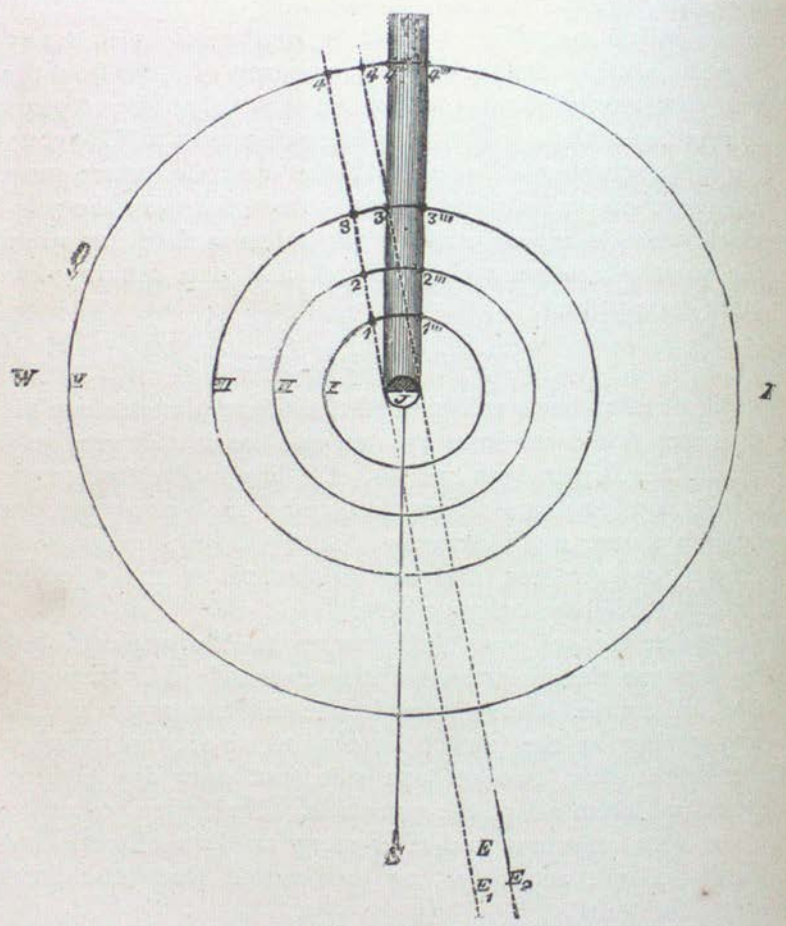
JUPITER, THE GIANT.

Jupiter has been well named the Giant planet, since his diameter is eleven times greater, and he is thirteen hundred times larger than our planet. His inclination is very small, and you now know that under such circumstances he enjoys very small changes of seasons. Jupiter has four moons, or satellites, and an illustration of the "Jovian System" is given on page 102.

Jupiter himself was well known to the ancients, but Galileo was the discoverer of the "moons." His telescope was, of course, a very imperfect instrument, and while he was gazing at the planet he noticed three stars close by the bright disc, two on one side, but next day Galileo perceived them all at the same side. Next time he looked there were only two, and after many anxious observations he found out, not only that Jupiter had three attendant stars, but four!

These moons were found to revolve round Jupiter in times varying from nearly two days to nearly sixteen days, according as they were at a less or greater distance from him. They were found to have their times of eclipses and

transits, etc., also. These moons act with respect to Jupiter very much as the inner planets act with respect to the sun, for observation showed Galileo that the satel-



The Jovian System.

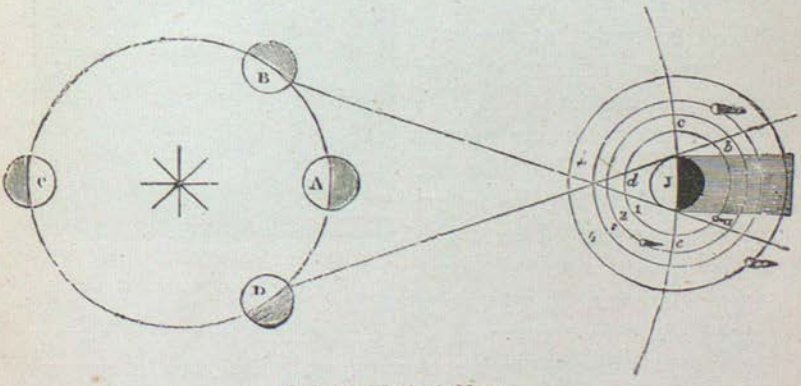
lites sometimes appeared on one side of the planet, and at other times on the opposite side.

From the diagram of the Jovian System we shall under-

stand the orbits of the moons, which are all of nearly equal size,—two thousand miles in diameter,—and cause eclipses of the sun to Jupiter. If the earth be in the same direction as the sun the moons are lost to view. The satellites disappear into the shadow, and are eclipsed at $1'''$, $2'''$, $3'''$, $4'''$, respectively, but they do not always come into view again immediately they have passed through the planet's shadow, because the earth is a little at one side of the sun. So when the satellite gets behind the edge of Jupiter, his shadow being on the opposite side to the satellite's, it is said that the "moon" is in "occultation"; when it disappears in the shadow it is "eclipsed." Cassini discovered the "transit" of Jupiter's moons. The annexed diagram illustrates the



Satellite in Transit.

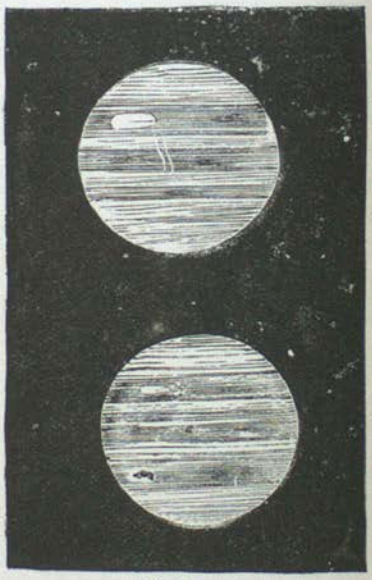


Eclipses of Jupiter's Moons.

eclipses, etc., very clearly. At the four points, A B C D, we have the earth; J is Jupiter with his moons; 1 2 3 4 is their orbits. At *a* moon No. 1 enters his shadow, and emerges at *b*. From the earth at D *a* will be visible, but

not *b*, because Jupiter is in the way. So at B, the coming out, or *emersion*, will be visible, but not the entrance into the shadow, or *immersion*. At A the satellite is in transit, *d*, on the disc of the planet, J.

From the observation of the eclipses of Jupiter's moons the rate of the transmission of light was discovered by Roëmer in 1675, and its progressive motion was calculated. The eclipses were noticed to take place later than the calculated time, when the planet was approaching conjunction. Roëmer suggested that the delay was owing to the greater distance the light had to travel —a distance equal to the diameter of the earth's orbit, or about 190,000,000 of miles. The time was about sixteen minutes. Light was found to travel at the rate of nearly 12,000,000 of miles a minute.



Jupiter.

Let us now endeavour to picture Jupiter himself. Here we have an illustration of the planet. He is the biggest, and the brightest, except Venus, of all the planets. He revolves at a distance of 476,000,000 of miles from the sun, and his year is equal to nearly twelve of ours, while his day is scarcely ten hours long, showing a rapidity more than twenty times the rate of our earth. Jupiter, therefore, must have a very much greater diameter than the earth.

There is much less sunlight and heat found on Jupiter than upon Earth, because he is so much farther from the

sun than we are, but at the same time the heat comes at less intervals than with us. And here the theory already noticed respecting the gradual cooling of the planets will be remembered. Jupiter, we can easily imagine, would take much longer to get cool than Mars or the earth, and, though his rapid rotation would assist him, he must be still in the midst of a glowing atmosphere without form and void—perhaps a furnace for cloud and vapour generation.

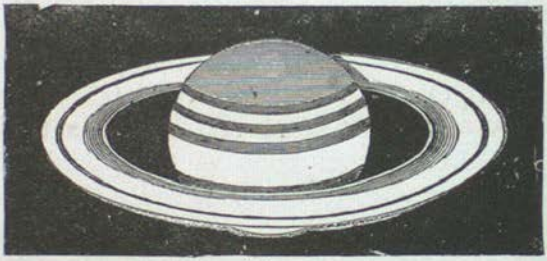
Now when Jupiter is examined with the telescope it will be seen that he is crossed by belts of vapour (*see* also page 40); and when we consider the results of the spectrum analysis of the planet, we may fairly assume that Jupiter is in a very heated state, and that we cannot really perceive the actual body of the planet at all yet. There is an immense quantity of water thus surrounding Jupiter, and he is still in the condition in which our earth was before geology grasps its state, and long ere vegetation or life appeared. The waters have yet to be "gathered together into one place," and the dry land has yet to appear upon Jupiter, who is a very juvenile, if a very enormous planet. Under these conditions we can safely assume that there are no inhabitants of Jupiter.

The belts, or zones, of Jupiter vary in hue, and the continual changes which are taking place in this cloud region tend to show that disturbances of great magnitude and importance are occurring.

It is useless to speculate upon what will happen in Jupiter when the disc is eventually cooled. The planet, we know, has not nearly reached maturity; the earth is in the full prime of its life, and the moon is dead and deserted. What the millions of years which must elapse before Jupiter has cooled may bring forth we need not try to find out. The earth will then, in all probability, be as dreary as the moon is now, and we shall have returned to dust.

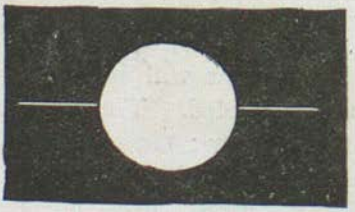
SATURN.

We now come to the most curious of all the planets—Saturn, which is an immense globe surrounded by a beautiful bright ring, or rather series of rings, and attended by eight moons. He appears to possess much the same constitution as Jupiter, but enveloped in an even denser



Saturn.

atmosphere than the latter. Saturn's diameter is about nine times greater than the earth; he revolves on an inclined axis in about ten hours, and has seasonal alternations of unequal length. His year is about thirty of ours (10,759 days). The most striking phenomena in connection with Saturn are his *rings*.

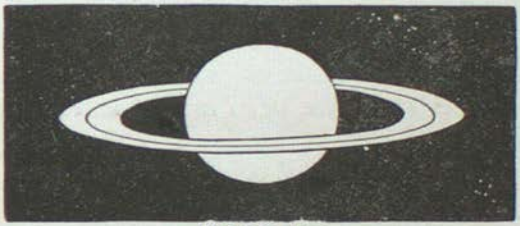


Saturn's rings at Equinox.

Saturn's rings are supposed to be a close agglomeration of stars, or satellites, revolving around the planet and encircling him in a belt. The rings are apparently broad and flat and thin, resembling roughly the horizon of a globe.

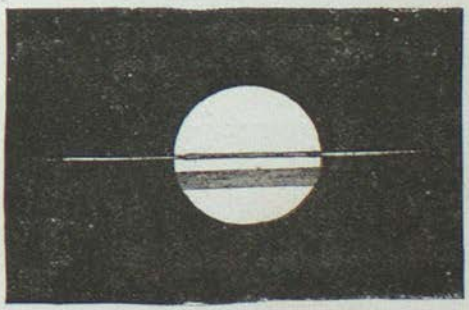
The globe of the planet is not exactly in the centre of the rings, which have been measured, and are approximately as follows :—

Diameter of exterior ring . . .	169,000	miles.
Diameter of interior ring . . .	124,000	,,
Diameter of innermost	100,000	,,
Interval between innermost ring and Saturn .	19,000	,,
Intervals between the rings . . .	18,000	,,
Thickness of the rings	130	,,
Breadth of the rings	37,000	,,



Enlarging ring.

The rings were first recognised as such by Huyghens in 1659, but Galileo had remarked the curious appearance the planet presented. Cassini confirmed Huyghens' discovery, and found that the ring was duplicated, and Mr. Ball made the same discovery. The two outermost rings



Ring shadow.

are very bright, the inner ring being darker and partially transparent, for the ball of Saturn can be perceived through it.

But the rings are not always so plainly seen as in the foregoing diagram. Sometimes they appear as a mere

line of light on each side of the planet, as shown in the previous pages. This occurs at the time of the equinox (page 106). By degrees, however, as they become inclined, they appear broader (page 107). The inner ring may be formed of vapour, but the outer ones are of something more solid, as the shadows they cast upon the planet, and it casts upon them, at certain times show.

Saturn possesses eight moons, seven of them revolving in orbits on the plane of the rings, but one is more inclined. These eight satellites have been named as follows :—

Name.	Distance from Saturn in radii of Saturn.	Miles.	Time of Revolution. d.	h.	sec.	Discoverer.
1 Mimas .	3·36 (about)	120,000		22	37	Herschel.
2 Enceladus	4·30 „	150,000	1	8	53	Herschel.
3 Tethys .	5·34 „	190,000	1	21	18	Cassini.
4 Dione . .	6·84 „	240,000	2	17	41	Cassini.
5 Rhea . .	9·55 „	340,000	4	12	25	Cassini.
6 Titan . .	22·15 „	790,000	15	22	41	Huyghens.
7 Hyperion.	26·78 „	945,000	21	7	7	Lassel and Bond.
8 Iapetus .	64·36 „	2,250,000	79	0	8	Cassini.

But these eight moons are not so interesting as those belonging to Jupiter, because the great distance they are away precludes much examination of them. They vary much in size, Titan being the largest, and perhaps equal to Mars, Iapetus being next in magnitude. The light of these satellites and the rings is no doubt very great in the aggregate, and must have a magnificent appearance in the heavens (compare page 46). Very

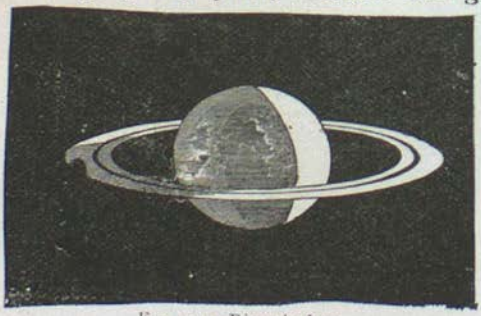


Fig. 594.—Ring shadow.

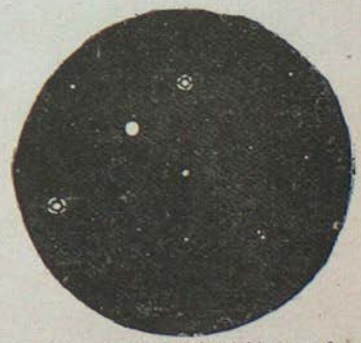
likely there are other attendants upon Saturn, but owing to the brilliancy of the rings it is impossible to distinguish them.

URANUS.

Uranus was discovered by Herschel in 1781, and has been called after its discoverer, and sometimes the "Georgium Sidus." It revolves at an enormous distance from the sun—viz., 1,753,000,000 of miles. It takes about eighty-four of our years (30,686 days) to go round the sun, and possesses four moons. It is very much larger than the earth—about four times the diameter, and forty times its volume. We can only speculate concerning its physical constitution, which is assumed to be similar to that of Jupiter, while the changes of temperature and seasons must vary immensely. The names of the moons are Ariel, Umbriel, Titania, and Oberon. The outer pair can be seen without much difficulty.

NEPTUNE.

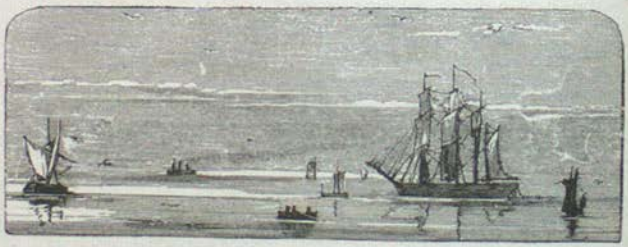
The existence of this planet was determined by calculation before it had been seen at all. Uranus was observed to be disturbed in his orbit, moving sometimes faster than at others; and even before Uranus had been discovered Saturn and Jupiter had been seen to be affected by some body in the system. M. Leverrier determined to ascertain the cause of this, and came to the conclusion that some other planet was influencing Uranus. The Newtonian theory here received a most convincing proof.



Neptune in field of view with stars of 6th, 7th, 8th, and 9th magnitudes.

While Leverrier was calculating, Mr Adams of Cambridge leaped to the same conclusion, and wrote the result of his calculations to Professor Airy, and the planet was seen, but not reported upon. Meantime Leverrier published his calculations, and the observers at Berlin detected the new planet in September 1846.

Very little can be said concerning Neptune, as its distance is too great for observation. It is at 2,746,000,000 of miles from the sun, and takes 164 years to go round it (60,126 days). It is about the same size as Uranus. It has one moon, which moves round the planet in 5^d 21^h, and is of great size.



CHAPTER VIII.—THE FIXED STARS.

FIXED STARS—MAGNITUDE OF THE STARS—CONSTELLATIONS—DESCRIPTIONS OF THE ZODIACAL CONSTELLATIONS—NORTHERN AND SOUTHERN STAR GROUPS—DISTANCE OF STARS.

WE have been considering the planets so far as they are known to astronomers, but no doubt we shall find out others some day beyond Neptune in space, for it must be assumed that there are other planets wandering about in the infinite firmament. At present, however, we cannot spare time for such speculation; we have got to peep at the stars and their groupings.

"What little bits of things the stars are," a child said once in our hearing; and there were others present who were inclined to believe that the tiny light spots we could see looked small—not because they were distant, but because they were of no great magnitude; and when those children were told that the tiny stars were "suns" like our sun, giving heat and light millions and millions of miles away,—and, so far as we can tell, some are much bigger and hotter than our own sun,—they were very much surprised indeed, and one little girl aptly quoted Dr. Watts :—

"Twinkle, twinkle, little star,
How I wonder what you are"!

Now let us endeavour to learn something about these apparently tiny specks, and why they "twinkle."

At a very early period in the history of astronomy the observers of the heavens grouped stars together in fancied resemblances to men or animals; and these "constellations," as they are termed, are combinations of *fixed stars*—that is, of stars which do not wander about as the planets do. But these so-called fixed stars have motions; they are only relatively fixed with reference to their positions to each other as they appear to revolve daily round the earth. Yet the stars have a movement of their own, which is termed their "proper motion."

It is to Halley that the discovery of these real star motions is due. He saw three very bright stars (Sirius, Aldebaran, and Arcturus) were not in the places they had been assigned. The sun also has been found to possess a "proper motion," and, with the planets, is travelling as determined by Sir J. Herschel, to a particular place in the constellation called Hercules. There are now star catalogues and star maps, for the heavens have been as closely surveyed as the earth, and by accurate observations it has now become possible to find the position of every star usually visible. Some of the stars are used as "clock" stars, by which sidereal time can be calculated accurately, and the clocks thereby corrected. The stars, though termed "fixed," are in perpetual movement—Arcturus at the rate of fifty miles a second, and others less. Only the rates of a few are known.

The number of the stars is beyond our calculation, and even the number of stars only visible in the telescope amount to millions, and these are called telescopic stars. The visible stars amount to about six thousand, and of course these are the brightest up to the sixth magnitude. There are more visible in the southern than in the northern hemisphere. The magnitudes of the stars range in classes

according to the brightness of the stars observed, for this is really the test from the first magnitude to the sixth; after that the telescopic stars are seen up to the fifteenth or sixteenth. We can only see about three thousand stars at any one time from any place, although, as remarked above, many millions may be observed with a good telescope, and as many more, probably twenty millions, are invisible.

We will now proceed to detail the constellations, which are familiar by name to everybody. We have already given the names of the zodiacal groups, which consist of many stars, each designated by a letter of the Greek alphabet so far as possible, then the Roman letters and numerals are employed. Thus α (Alpha) is the most brilliant star ; β (Beta) the next bright; γ (Gamma) the next, and so on ; so the relative brilliancy of the stars in the constellation is indicated, but not the very biggest star of the first magnitude is intended by α, for the star δ in one constellation may equal α in another. John Bayer originated this method in 1603.

The arrangement of the constellations is plunged in the obscurity of ages, but B.C. 370 there were forty-five thus grouped. There are northern and southern constellations which are visible above our old friends Aries, Taurus, Cancer, etc. We will, as in duty bound, consider our old acquaintances first, and then give a list of the northern and southern groups of stars ; but we shall find that the forms are in the greater part due to the imagination of the ancients, and do not bear out our ideas of the animals they are supposed to represent, while at the same time they cross and recross with other constellations in the skies in a very puzzling way.

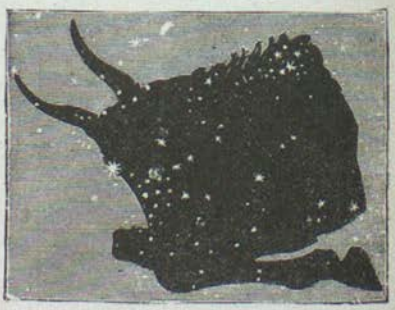
The first constellation is ARIES, the Ram, which is celebrated in mythology as the proud possessor of the Golden Fleece, which we may remember was seized and

carried away by Jason and the Argonauts. The Hellespont is so called from Helle, who fell from the Ram's back when being carried upon it over the Black Sea. The Ram is here represented with the equinoctial ring.



Aries.

We perceive in Aries two very bright stars near the head These are (α) Arietis and (γ) Sheretan. The signs and constellations do not now correspond as they used to do, because of the change in the position of the stars, which gives rise to the Precession of the Equinoxes (*vide ante.*, p. 52), so that the stars which two thousand years ago were in conjunction with the sun, are much more to the eastward. In olden time (when astronomy was young), the sun entered Aries on the 21st March, and now a change has taken place. But in about another twenty thousand years, they will all come right again. This will be perceived by reference to the celestial globe. The Ram has sixty-six stars in his constitution.



Taurus.

TAURUS, the Bull, is the next constellation. He received his name from the celebrated animal into which Jupiter transformed himself when he wished to carry away Europa. The star Aldebran (α) is the end of a kind of V in the Bull's face. The Pleiades are on the shoulder to the right. This

cluster of twinkling stars is well known, and will guide the observer towards the imaginary Bull, which we must nowadays describe as rather a fanciful delineation. Europe is called after Europa, because Jupiter, as a Bull, carried her to this continent. There are 141 stars in Taurus, according to the number found in the list of Aratus, and a great many more exist.

GEMINI, the Twins, which are supposed to be Castor and Pollux, though it is believed that two goats were the original sign—which statement, taken in connection with the ram and the bull, that were also turned out in the spring-time, may have something to recommend it. But now Castor and Pollux are generally recognized as the constellation. During the expedition for the Golden Fleece, the electric appearance, now known as St. Elmo's Fire, became visible upon them, and their effigies were placed in the forepart of ships as a good omen. This led to the adoption of the "figure-head." They were made into stars when Pollux was immortalized by Jupiter, for he divided the boon with his brother. The planet Uranus was discovered near this constellation, which contains eighty-five stars.



Gemini

CANCER, the Crab, is the next in order, and the only derivation we can find for this is that Juno sent a crab to attack Hercules when he was busily engaged with the many-headed Hydra. The crab was directed to pinch the hero's foot, but it appears rather a lame device for the Queen to adopt. The crab, however, was killed by

Hercules, and placed amongst the stars by Juno as a reward; so he gained immortality cheaply. He, Cancer, contains more than eighty stars, but none of them of any particular note. Some writers explain the sign as reminding the ancients of "the retrograde movement of the sun to the north"; but as a crab does not move "backwards," we will still adhere to mythology as equally satisfactory at any rate. Cancer, however, was termed the "northern gate of the sun."



Cancer.

The next is LEO, the Lion, which came round in summer and at the period of much heat, so this fierce animal may have been chosen to represent that season. But mythology will have us credit the Nemæan Lion sent against Hercules by Juno as the origin of this constellation. The lion was, like the crab, placed amongst the stars when he was killed. He is a very brilliant constellation, and a very bright star called Regulus is to be seen in his chest —"Cor Leonis." Another very fine star of the second magnitude is observable in the tail. The Lion consists of ninety-five stars, the principal ones being of the first and second magnitudes.



Leo.

VIRGO is supposed to be outlined by a very rich cluster

of stars, and one of the first magnitude. The Virgin is by some supposed to be Astræa, the goddess, but is more likely referable to a girl gleaning, or holding an ear of corn in semblance of the harvest. This constellation contains more than one hundred stars. One of them in the wheat-ear is a particularly brilliant one, and noted for its "solitary splendour," as no star of large magnitude is near it. The Arabs used to call it the Solitary Simak; *Spica Virginis* is the modern name.



Virgo.



Libra.

LIBRA, which follows, may either indicate the balance, or scales of justice, of Astræa, or the equal day and night at the autumnal equinox. Virgil mentions Astræa's balance, and thus we have a classical authority for the very mythological view of the two foregoing constellations. Libra is not very distinct; it contains fifty-one stars four of which are very bright.



Scorpio.

SCORPIO, the Scorpion, according to classical writers, encountered Orion who is also met with in the stellar universe. The scorpion stung Orion because he declared there was no living creature he

could not overcome by force. On the other hand, this sign may have some reference to the unhealthy time of year, and the prevalence of disease about the time that *Scorpio* appeared. A beautiful star of reddish hue and of the first magnitude is prominent amongst the brilliant assembly of the Scorpion's forty-four stars.



Sagittarius.

SAGITTARIUS, the Archer, is, as one can see, a Centaur, and said to be Chiron, who was wounded by Hercules, and cured by being taken up to Heaven by Jupiter. This Chiron is represented as a great patron of the arts, and thus the fable may be said to exemplify the proverb, "Art is long, time in fleeting"; for readers of mythology will find much more in the legends than is apparent on the surface. But we can now only regard the Centaur from an astronomical, and not a philosophical standpoint. Sagittarius has no very brilliant stars. He is close to the Milky Way, and contains sixty-nine stars five forming a sort of V in the bow, sometimes compared to a ladle or "dipper."



Capricornus.

CAPRICORNUS, the Goat, is supposed to be *Pan*—"the great god Pan," who turned himself into a

goat. The sun was in Capricornus at mid-winter, so the "southern gate of the sun" was a title bestowed upon him. But now the constellation is later. It does not include any very striking stars, of which there are fifty-one in the "Goat."

AQUARIUS, or the Waterbearer, may have referred to wet weather, or as others declare, to Ganymede, the Cupbearer. There are four stars in the waterpot like a Y; and more than one hundred stars of small brilliancy are included in this constellation. But here again fancy must come to our assistance, for without a diagram the ordinary observer could not distinguish the Waterbearer, as he is supposed to exist.



Aquarius.

PISCES, the Fishes, are not plainly defined. It is supposed that Venus and Cupid turned themselves into fish when the Titans assailed Heaven. This Constellation occupies a triangle in the sky.



Pisces.

The foregoing are the zodiacal constellations, and may be more easily remembered by repeating an old rhyme, which runs as follows:—

"The Ram, the Bull, the Heavenly Twins;
Then, next the Crab, the Lion shines,
The Virgin, and the Scales;
The Scorpion, Archer, and the Goat,
The Man who holds the Watering Pot,
The Fish with glittering tails."

The arrangement of the various Constellations at which we have so rapidly glanced, as well as of those that follow, has been the work of many different periods. Aratus and Ptolemy are the oldest enumerators, but modern research has added immensely to the store of knowledge. Many of the most prominent stars were named by Grecian and Arabian observers, and many of the names are still retained—such as Arcturus, Rigel, Capella, and others.

The Northern Constellations.

There are, altogether, thirty-five of these, as per list on next page. It is of course impossible to describe them all, but we will make a few remarks respecting those which will be distinguished most readily, and the manner of finding out particular stars. There are star maps published, and with a little attention and reading, a great many very pleasant evening excursions may be made across the sky, with or without a telescope. The following is the list of the northern constellations. We have put them in various types to indicate the most important, those in capital letters being the chief, and so on. We have not mentioned all that might be written down, but the list is sufficiently long, and includes those generally observable.

NAME OF CONSTELLATION.		"AUTHOR."	No. OF STARS
URSA MAJOR . .	The Great Bear	Aratus	87
Ursa Minor . . .	The Lesser Bear	"	24
Perseus	Perseus	"	59
Auriga	The Waggoner	"	66
Boötes	The Herdsman (Boötes)	"	54
Draco	The Dragon	"	80
Cepheus	Cepheus	"	35
Canes Venatici . .	The Greyhounds / Hunting Dogs	Hevelius	25
Cor Caroli . . .	Heart of Charles	Halley	3
Triangulum . . .	The Triangle	Aratus	16
Triangulum Minor.	The Little Triangle	Hevelius	10
Musca	The Fly	Bode	6
Lynx	The Lynx	Hevelius	44
Leo Minor . . .	The Lesser Lion	"	53
Corna Berenices .	Berenice's Hair	Tycho Brahé	43
Camelopardalis . .	The Giraffe	Hevelius	58
Mons Menelaus .	Mount Menalaus	"	11
Corona Borealis .	The Northern Crown	Aratus	21
Serpens	The Serpent	"	64
Scutum Sobieski .	Sobieski's Shield.	Hevelius	8
Hercules	Hercules	Aratus	113
Serpentarius . . .	The Serpent-bearer	"	74
Taurus Poniatowski	Poniatowski's Bull	Poczobat	7
LYRA	The Harp, or Lyre	Aratus	22
Vulpecula et Anser	Fox and Goose	Hevelius	37
Sagitta.	The Arrow	Aratus	18
AQUILA	The Eagle	"	71
Delphinus . . .	The Dolphin	"	18
Cygnus	The Swan	"	81
CASSIOPEIA . . .	The Lady's Chair	"	55
Equuleus	The Little Horse	Ptolemy	10
Lacerta	The Lizard	Hevelius	16
Pegasus	Pegasus (Flying Horse)	Aratus	89
Andromeda . . .	Andromeda	"	66
Tarandus	The Reindeer	Lemounier	12

(There are a few others marked in continental maps.)

The GREAT BEAR, or "Charles's Wain," or the "Plough," as Ursa Major is variously called, is of great value in indicating the pole star, which, when once known, can never be mistaken. This constellation has also been termed the "Dipper," and is very conspicuous in the northern hemi-

sphere. The three stars form the bear's tail, or the handle of the "plough"; the others form the body, Charles's Wain, or "Karl-Wagen," the German term for peasant's cart, is represented by the quadrangle forming the cart, and the other three stars are the horses.

The "Pointers" are the two end stars, and if a line be followed northwards from them it will lead close to *Polaris*, the principal star in the lesser bear. This pole star is of



The Great Bear.

a very great brightness, and peeps out, almost isolated with a pure lustre. The names of the pointers are Dubhe and Menak. The star at the tail-tip is Benetnasch, then Mizar and Alioth. Megrez and Phad are the remaining pair. We append a rough outline of the bear, for the information of those who have not yet noticed it.

The Lesser Bear is not so important as his lder. brother as regards size, but he is very useful to astronoemers

He resembles the Great Bear in appearance, but is smaller, and the positions of the stars are inverted. In the cut on page 142 you see the little bear swinging round the polar star, which is at the tip of the Lesser Bear's tail, so any one will be enabled to find him if they look for the polar star, and then count the three stars away from it, and the four in the body. The Great Bear's tail points in the other direction. This movement of the earth's axis by displacing the equinoctial points, alters the "declination" and "right ascension" of the stars (compare page 13). So Polaris is gradually approaching the actual polar point. In about 200 years he will have got as close as he can, and will then begin to recede from it, and in about 12,500 years after he will reach his most distant point.

POLARIS, the Pole Star, was called "Cynosure" by the ancients, and thus we can understand the quotation, "Cynosure of neighbouring eyes," when a person or object is very attractive. The pole star was the point to which all looked. There are some other very important stars in these constellations. For instance, in—

Perseus we have Algenib and Algol, of second magnitude.
Auriga we have Capella, of the first magnitude.
Boötes we have Arcturus, of the first magnitude.
Lyra we have Vega, a very large and bright star.
Aquilla, Altair, also a very beautiful star.
In Cygnus there is Denet, of the first magnitude.

These stars are also designated by the Greek letters—*a*, lyræ, or the first in the Lyre—that is, Vega; and so on for all, according to rank, as already explained.

SOUTHERN CONSTELLATIONS.

We must pass on to the southern constellations, of which there are forty-six; the principal ones are in capital letters :—

NAME OF CONSTELLATION.		"AUTHOR"	No. OF STARS
*Phœnix	The Phœnix	Bayer	13
Apparatus Sculptoris	The Sculptor's Tools	Lacaille	12
Eridanus Fluvius	The River Po	Aratus	84
*Hydrus	The Water-snake	Bayer	10
Cetus	The Whale	Aratus	97
Fornax Chemica	The Furnace	Lacaille	14
*Horologium	The Clock	"	12
*Rheticulus Rhomboidialus	The Rhomboidal Net	"	10
*Xiphias Dorado	The Sword-fish	Bayer	7
*Celapraxitels	The Engraver's Tools	Lacaille	16
Lepus	The Hare	Aratus	19
Columba Noachi	Noah's Dove	Halley	10
ORION	Orion	Aratus	78
Argo Navis	The ship Argo	"	64
CANIS MAJOR	The Great Dog	"	31
Equuleus Pictoris	The Easel	Lacaille	8
Monoceros	The Unicorn	Hevelius	31
Canis Minor	The Lesser Dog	Ptolemy	14
*Chameleon	The Chameleon	Bayer	10
Pyxis Nautica	The Mariner's Compass	Lacaille	4
*Piscis Volans	The Flying Fish	Bayer	8
Hydra.	The Snake	Aratus	60
Sextans	The Sextant	Hevelius	41
*Rober Carolinum	Charlie's Oak	Halley	12
Antlia Pnuematica	The Air Pump	Lacaille	3
Crater	The Cup	Aratus	31
Corvus	The Crow	"	9
**Crux Australis.*	The Southern Cross	Royer	6
Apis Musca	The South Fly	Bayer	4
*Avis Indica	The Bird of Paradise.	"	11
*Circinus	The Compass	Lacaille	4
Centaurus	The Centaur	Aratus	35
Lupus.	The Wolf	"	24
Norma	The Square	Lacaille	12
*Triangulum Australis	The Southern Triangle	Bayer	5
**Ara.*	The Altar	Aratus	9
*Telescopium.	The Telescope	Lacaille	9
Corona Australis	The Southern Crown	Ptolemy	12
*Pavo	The Peacock	Bayer	14
*Indus	The Indian	"	12
Microscopium	The Microscope	Lacaille	10
*Octans Hadliensis	Hadley's Octant	"	43
*Grus	The Crane	Bayer	14
Toucan	The Toucan	"	9
Pisces Australis	The Southern Fish	Aratus	24
*Mons Mensa	Table Mountain	Lacaille	30

We need only describe Orion and Canis Major, the principal groups. The former certainly constitutes the most glorious group, and it is visible to all the world, because the equinoctial passes through it.

ORION, as we have said, can be viewed from either hemisphere, and so can some others; but those marked with an asterisk in the foregoing list are not visible in the latitude of London.



Orion.

Orion is a very brilliant constellation, and contains two fine stars of the first magnitude, and some of the second. The former are Betelgeux and Rigel. Bellatrix is the third in order. The "belt" is formed of three bright stars, and the sword is visible as five stars just below. Canis Major possesses Sirius, a very fine star (the dog star). Canis Minor has two of the first and second magnitude, and Hydra has one of the first. The Southern Cross is a beautiful constellation, invisible in our latitude, but familiar to sailors in the Southern Seas.

THE STARS' DISTANCE AND MAGNITUDE.

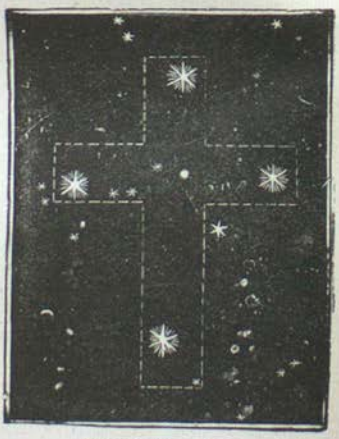
When we gaze up into the sky at night, we see the stars twinkling far away, and we may remark here that this twinkling of the stars is due to the atmosphere and the changes in its power of refraction, and of course the star's light changes its direction. But if we ascend in a balloon into very high and rarefied strata of the air, we

will find the twinkling less. We have given the number of the stars according to Flamstead, but the larger the telescope the greater will be the number of stars we shall see, numbers again being too far even for our perfected instruments.



Polaris.

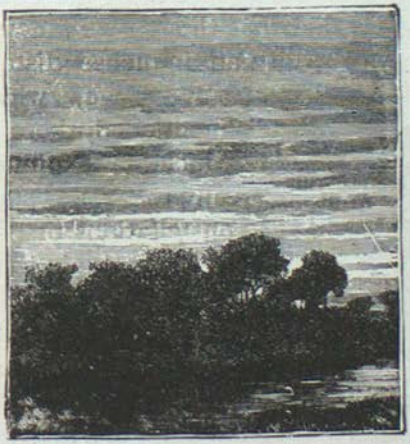
But we can gain some idea of the magnitude of the stars when we consider the distance to arrive at, which is a most difficult task, for figures seem scarcely long enough to count the millions of miles, and no instrument can detect the parallax. Even supposing the parallax to be a very small fraction of a degree we should get a result equalling trillions of miles. No. 61 in Cygni was at one time continually observed by Professor Bessel, and he found that its distance—and it is the nearest star—is *sixty-two and a half trillions of miles.*



The Southern Cross.

Let us consider what this means. Light comes to us from the sun (91,000,000 of miles) in about eight minutes, and travels at the rate of something like 186,000 miles in a second. But even at that astounding rate the light from the star called 61 Cygni took ten years to reach the earth; and there are stars whose light has never yet reached the earth, although the gleam may have been travelling at 186,000 miles a second for thousands of years. And we may presume that though we still see the light of stars, some of them may be dead, but the light left is still progressing to us through space.

So we must conclude that some stars which look large, as do Vega and Sirius for instance, must be enormous "suns," a great deal larger than our sun, and the stars are each the centre of invisible systems just as our sun is the centre of the "solar" system. Vega is a tremendous star, and shines with her own light as do all other visible stars; for reflected light, so very visible in the moon, which is close to us, would be quite invisible at such tremendous distances. So we must call these stars "suns," and may add an apparently astonishing fact, that our own sun is merely one of the stars in the Galaxy, or "Milky Way"!



CHAPTER IX.—THE STARS. (*Continued.*)

DOUBLE AND MULTIPLE STARS—COLOURED AND VARIABLE STARS—CLUSTERS, GROUPS, AND NEBULÆ—THE GALAXY, OR MILKY WAY—HOW TO FIND OUT THE PRINCIPAL STARS.

ALTHOUGH not very clearly visible to the naked eye, there are in the sky some pairs of stars very close together apparently; but when these double stars are examined with a good telescope we find that though we fancy they are two stars very close, in reality an immense distance separates them. By Vega, which we have already mentioned, there is apparently a star, which on examination will be found really to be two stars. It is also in the constellations of the Lyre, but of much lower magnitude than Vega. But in some instances there are three or four stars thus placed together, and the frequency of the occurrence of this fact establishes the farther fact that these combinations are not accidental—that the stars are interdependent and physically connected.



γ Leonis.

There are now at least six thousand double stars known,*

* Mr. Burnham has lately given a list of two hundred and fifty-one new double stars, and in the Astronomical Society's proceedings there is a list of ten thousand.

and this is a very small proportion of the forty millions or so of suns which are believed to exist in space. But of these six thousand a larger proportion have been ascertained to be physically connected. More than six hundred of these pairs are double suns, while again there are other combinations of three and perhaps more. When two are thus connected we have what are termed binary systems, and when more are associated they are called triple and multiple stars. An example of the last-mentioned class is the small star above mentioned near Vega. It is ϵ Lyræ, and is a double of a double. In ordinary telescopes this will not be perceived, but with a high power the combination will be noticed. The same phenomenon is observable in one of the stars of Hercules and in Andromeda.

The revolution of these double suns, or binary systems, has been closely observed, and Professor Newcomb has given us a list of the binary systems of short period which are well determined. These are as follows :—

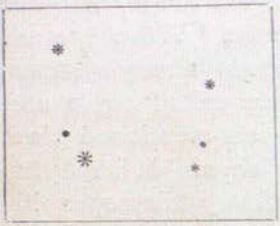
42 Coronæ . .	26 years.	ξ Ursæ Majoris .	63 years.
ζ Herculis . .	35 years.	η Coronæ Borealis .	67 years.
Struve 3,121 . .	40 years.	α Centauri . .	77 years.
η Coronæ . .	40 years.	μ Ophiuchi . .	92 years.
Sirius . . .	50 years.	λ Ophiuchi . .	96 years.
ξ Cancri . .	58 years.	ξ Scorpii . .	98 years.

It must be borne in mind that although these double stars appear close together from our standpoint, they may be far apart—one behind the other in a straight line. When such "pairs" exist they are known as optical pairs, or optically double stars, as distinguished from the actually physical "pairs" which revolve round the centre of a system. In Orion there has been discovered a regular system, and the θ in Orion, which appears in a common



Monocerotis.

telescope a moderate star, and to the unaided eye only a speck of light, is really composed of seven stars—four are set in the form of a trapezium, as figured in the diagram in the margin by dots and asterisks. Two of these have been ascertained to possess attendants indicated by dots, and a seventh star was discovered by Lassell, and Humboldt remarks that in all probability this apparently tiny star in the constellation Orion constitutes a real system, for the five smaller stars have the same proper motion as the principal one.



Trapezium of Orion (Herschel).

Thus our imagination almost fails to grasp the infinity of the systems with our single sun, and with the distant double and even triple suns round which planets revolve perfectly independent of the other systems, as we are independent of them possessing heat and light from their own sun or suns as we receive it from ours, day and night seasons succeeding each other, and the wondrous varieties of the light produced by the appearance or withdrawal of a sun or two in the firmament of those most distant planets. These suns being double or triple would affect each other; the composition of the light given forth would produce—as we may assume—varying effects. We know something about the light of the stars by the spectroscope, and the colours of stars are due to the vapour which takes away a certain part of the light emitted, leaving the remainder to descend through the atmosphere to us.



η Coronæ.



Boötes.

Binary stars are most numerous of the doubles; for

instance Castor, η Coronæ, Rigel, Polaris, Mivac, γ Leonis, γ Virginis, ξ Ursæ Majoris, α Hercules, 36 Andromedæ, λ Ophiuchi, and π Aquilæ. The illustration in the margin is Castor (or *a* Geminorum), the most northerly of the Twins. The η Coronæ is also figured, as are Polaris (*see* page 126), Boötes, Rigel, and γ Leonis.



Castor.

The cuts herewith illustrate the relative positions at the periods named of the "doubles," and of the revolution of suns around other suns as mentioned. As a consequence of their proper motion the binary stars appear to vary in their distances from each other, as in the topmost of the three cuts on page 133 representing γ Virginis. The stars have gradually approached each other, and so are the stars in Castor approximating, and when they have closed, and have appeared almost as a single star, as they will do, they will take open order again, and so on till the end.

The shortest time occupied by a double star in its revolution is thirty-five years, and we have already given some of those which have been ascertained. We will close this section with a few other examples. For instance, γ Virginis revolves in one hundred and fifty years, Castor in two hundred and forty years, 4 Aquarii in three hundred years, 37 Pegasi in five hundred years. There are numerous other instances up to a period of three thousand years, and about eight hundred of these binary systems are known. We have mentioned that there are two or more suns in the multiple systems. These suns are the cause of the different colours of the stars.



Rigel.

Colours of the Stars.

The question of star-colour follows naturally the consideration of the multiple stars; for although single stars have been observed of a ruddy colour, there are no instances of a blue or green one unattended by a companion. This colouring has been attributed to the contrast between multiple stars, for the colours are frequently complementary; but investigation has shown that this cannot be the case. For instances have been known in which, when two are thus associated, and one is concealed from us, the other is just as bright, and retains its former colour.

Of course in cases in which colour is apparent to the unaided vision, only the brightest stars betray colour. Antares, Betelgeuse and Aldebran are red (orange) colour. Sirius and Canopus are white. Arcturus and Capella are yellowish, so is Pollux. Vega is bluish-white. These appearances are, of course, much more marked when the stars are examined through the telescope, and telescopic stars—which are stars unobservable without a glass—are very much coloured, and the multiple stars give us blue, green, violet, and other tints, besides those already mentioned.

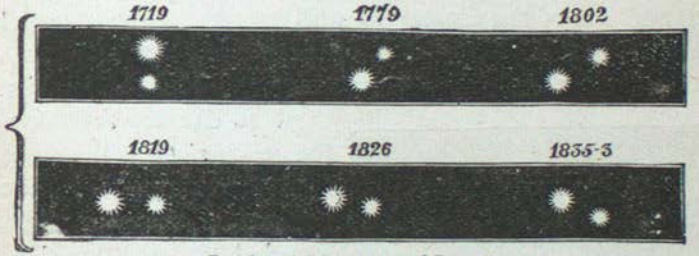
Again, these coloured stars do not always remain the same colour. Sirius was once red; Mars was at times white. Spectrum analysis shows that the colours of many are due to absorption by the vapours of some of the rays; and the existence of certain vapours may cut off some, and at other times other vapours may exist and cut off other rays, and so the colours may be changed. Struve gives the following list of binary complements of "multiple" stars:—

Pairs consisting of a blue and white principal star	. .	53
" "	and a light yellow principal star .	52
" "	a yellow or red principal star .	52
" "	a green principal star . . .	16

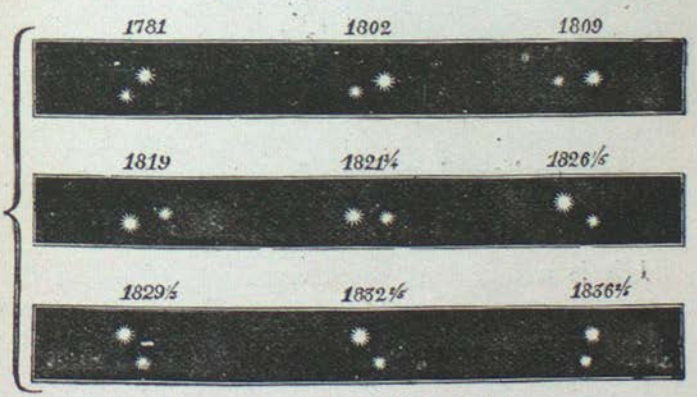
We need scarcely pursue this question farther, though many ideas concerning the coloured stars will arise in every thoughtful reader's mind. Supposing that every system has its sun or suns, can we fancy the effects of a



Position of the two stars of γ Virginis.*



Position of the two stars of Castor.*



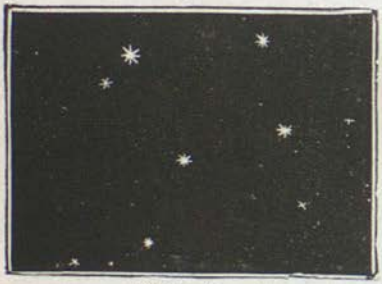
Position of the two stars of ξ Ursæ Majoris.

green or blue or violet sunlight—a light unmixed? To employ the words of Sir John Herschel—"It may be more easily suggested in words than conceived in imagination what variety of illumination two suns, a red and a green,

or a yellow and blue one, must afford to a planet circulating round either—or what charming contrasts and graceful vicissitudes a red and a green day, for instance, alternating with a white one and with darkness, might arise from the presence or absence of one or other or both above the horizon."

Lost and New Stars.

We may have perhaps read the "Lost Pleiad," and wondered what has become of the star supposed to have dropped out of the cluster so well known in the constellation Taurus—the Pleiades. There are seven stars, of which six are visible to the average eye, and the ancients used to declare that one of the seven sisters (the daughters of Atlas and Pleione) hid herself because she had married a mortal, while all her sisters wedded gods. It is not improbable that one of the seven, formerly distinguishable with the unassisted eye, may have disappeared or been lost; but it is certain that strong eyesight can see more than seven now, and in the telescope there are about one hundred.

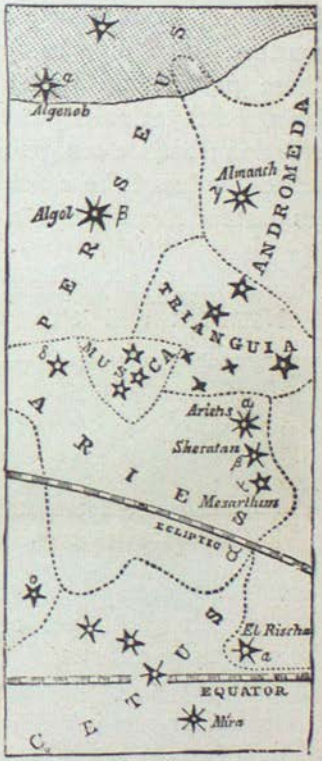


Cassiopeia.

And it is a fact that some stars whose places have been carefully marked in the catalogue have subsequently disappeared. Many errors may have been made, and stars put down where no star existed, so a succeeding observer has not been able to find the star indicated. But, on the other hand, we may admit that stars have been lost to sight, and to compensate us for any such disappearances new stars are frequently observed, and these are very remarkable phenomena. About 121 B.C. Hip-

parchus perceived a new star, which was visible even in the daytime, and on subsequent occasions others came into existence—viz., in the years 945, 1264, and 1572. In the last-mentioned year Tycho Brahé suddenly perceived the new star, which was at first very brilliant. It grew fainter and fainter, after first gaining in intensity, and disappeared entirely in 1574; and at other times stars have been seen which remained only for a short time, and then disappeared.

The star discovered by Tycho Brahé was seen by him when walking across the fields one night, and he encountered peasants who were gazing at the new luminary. It was so bright that it threw a shadow from Brahé's stick. The new arrival appeared in "Cassiopeia," under the lady's chair, forming, as pictured in the diagram, an irregular square. The strange star is the largest.



Star-Map.

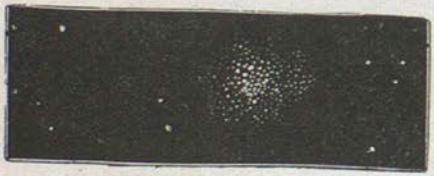
Some stars exhibit extraordinary fluctuations, and one discovered by Mr. Birmingham in 1866, decreased rapidly and sank away to about the tenth magnitude, and then got brighter, and again diminished in splendour. The "Eta" Argûs has also been subjected to many fluctuations likewise, and such alterations have gained for these luminaries the name of "Variable Stars."

In the accompanying little chart there will be perceived two particular stars, named Algol, "the demon," and Mira

"the wonderful." The latter is the most celebrated for its variable qualities, and its cycle of change occupies nearly one of our years. For a few days it appears very bright, and then fades away for about three months, to disappear for five months, and then it reappears again, increasing in brilliancy up to the second magnitude for another three months or so. Some people account for these phenomena by stating that the sides of the star being less luminous present the dark and light portions in rotation ; but we can give no satisfactory explanation of the reason, unless it be caused by an aggregation of spots upon its surface like sun-spots on our sun, or perhaps by eclipse.

STAR-CLUSTERS AND NEBULÆ.

NEBULÆ and STAR-CLUSTERS are numerous in the heavens. The most important are the Great Nebulæ in Orion and in Andromeda. But there are other very beautiful "patches" of luminous matter or cloud appearances composed of minute stars invisible to the naked eye. We annex specimens of the Nebulæ, one or two having been already inserted. There must be thousands of these star-clouds, and they have been classified by Sir John Herschel from Sir William's discoveries as follows :—

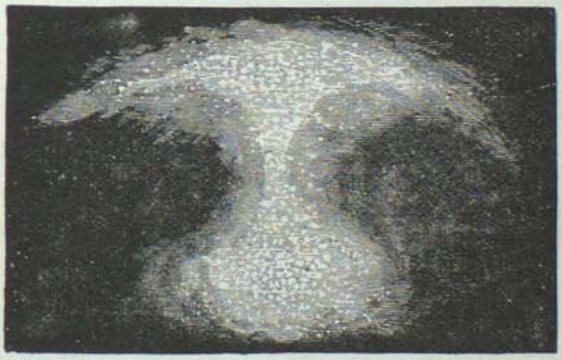


Nebulæ in Pegasus.

1. Clusters of stars, in which the stars are clearly distinguishable, divided again into regular and irregular clusters.
2. Resolvable Nebulæ, which may be separated into distinct stars under powerful telescopes.
3. Nebulæ, in which there is no appearance whatever of stars, divided into classes according to brightness, etc.

4. Planetary Nebulæ.
5. Stellar Nebulæ.
6. Nebulous Stars.

We learn also from the foregoing authority that Nebulæ affect a certain district; that is, they have, as it were, a preference for it, and are not distributed in a random manner over the heavens, and are found in Leo, Leo Minor, Ursa Major, Canes Venatici, Coma, Böotes, and Virgo, and more sparingly in Aries, Taurus, Orion, Perseus, Draco, Hercules, Lyra, etc. Nebulæ are found associated with stars, as is the case with η Argus; these are called



Dumb bell Nebulæ.

nebulous stars, and in the case of this particular star many very interesting investigations have been made. The Nebulæ are as equally variable as the stars they surround.

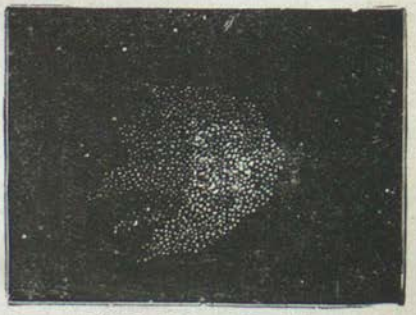
What is termed the Nebular Hypothesis was put forward by La Place, and by it he endeavoured to account for the regular development of the stellar system, which is supposed to have originated from an immense nebular cloud This immense mass would rotate and contract, and the outer portions would separate and develop in rings like Saturn's rings. Then the rings break into

separate portions, and each portion condenses into a planet, or the small "bits" travel round the sun like asteroids, and in this manner various systems were formed. This theory was considered to be quite exploded when stars were discerned in nebulæ by the more recent telescopes; but then the spectroscope came to our aid, and it was discovered that there were some nebulæ which are simply masses of glowing gas or aggregations of stones which are dashing against each other in so forcible a manner as to produce heat and luminosity. Mr. Lockyer appears to favour the latter theory as to nebulæ.



Nebulæ in Perseus.

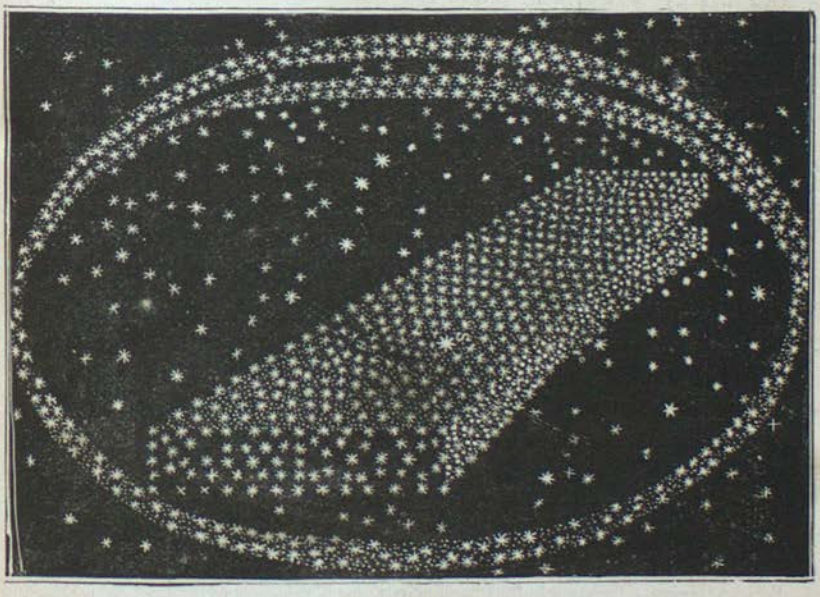
Mr. Proctor, however, has put forward a hypothesis that the star or meteor showers are the original cause of the sidereal system, and this rain of meteors has fallen for all time, gradually consolidating into orbs. The fact that the constituents of sun, earth and planets, comets and meteors being fundamentally the same lends probability to this hypothesis, which is fully explained by the author of it.



Nebulæ in Canes Venatici.

THE MILKY WAY.

The Galaxy is familiar to all readers, and although visible all the year round, is perceived more plainly in August, September, and October, or at the beginning and ending of that period. This zone of stars was of course well known to the ancients, but it is to Galileo that we owe the first important information about the Galaxy; he decided that it was formed of stars. Sir John Herschel



The Milky Way.

investigated the subject very closely, and to him much of the information concerning the Milky Way is due.

It is not very distinct in the north, but as it advances from Cepheus southwards by the Unicorn, it gets clearer, and opens out in Argo, and descends still south, becoming brighter near the Southern Cross. It then passes northward again, dividing into two branches, one of which dies

out, and then over Sagittarius, and so on to Cygnus, then to Cassiopeia and the starting-point. The number of stars in the Galaxy is about 18,000,000.

In this wonderful zone of stars the centre of our system, the sun, is placed. It was supposed to be divided as in the diagram on page 139; the inner portion being the stars seen in their thickness, and the outer ring representing the stars viewed in the direction of the length and breadth. But afterwards, Herschel modified his opinions respecting the Milky Way, and since his death many astronomers—and Mr. Proctor more particularly—have devoted considerable time to an examination of this wonderful zone of stars; which, it must be remembered, is not a continuous stream; it is a series of luminous patches. On this point Professor Nichol says:—

"It is only to the most careless glance that the Milky Way appears a continuous zone. Let the naked eye rest thoughtfully on any part of it, and if circumstances are favourable, it will stand out rather as an accumulation of patches and streams of light in every conceivable variety of form and brightness; now side by side, now heaped on each other, again spanning across dark spaces . . . and at other times darting off into the neighbouring skies in branches of capricious length and shape, which gradually thin away and disappear."

The Milky Way has its greatest breadth in the "Swan," and in the "Eagle" constellation it divides itself. In the "Southern Triangle" the zone is brightest, and in the "Southern Cross" the hole or space, termed by sailors the "Coal Sack," is very distinct. It then contracts and expands, and there is in Argo another gap. Then it is lost for a space, then it branches out, and soon crosses the Equator, dilates, contracts, opens out again, and so returns to the "Swan" again.

Philosophers have frequently discoursed upon this

phenomenon, but all statements must remain more or less speculative. From Kepler's to the present time astronomers have been considering the Milky Way, and when the Nebular theory was given up, when the Galaxy was found to be composed of stars, there was, as we have noticed, the idea of the ring and the cloven disc. Mr. R. Proctor has likened the Galaxy to a coiled serpent, and considers the openings in the Milky Way as evidence that the stratum of stars is limited, and that here we can see beyond it. In fact, it would appear that it is a very complicated question ; and as the zone itself is complicated "with outlying branches beyond the range of our most powerful telescopes," so an actual knowledge of the Milky Way is beyond us at present. It is composed of most extraordinary aggregations of stars, which appear not only impossible to count, but each one to be independent of the other. Thus we must conclude our rapid survey of the Milky Way, and close with Mr. Proctor's remark in his "Universe of Stars." "The sidereal system," he says, "is altogether more complicated, altogether more varied in structure than has hitherto been supposed. Within one and the same region co-exist stars of many orders of real magnitude, the greatest being thousands of times larger than the least. All the Nebulæ hitherto discovered, whether gaseous or stellar, irregular, planetary, ring-formed, or elliptic, exist within the limits of the sidereal system. They all form part and parcel of that wonderful system, whose nearer and brighter parts constitute the glories of our nocturnal heavens."

And a little reflection will show how true this is. Not very long ago in the world's life the solar system was supposed to consist of one sun with a few planets wandering around him. Then some more were found, and they were called "satellites." For a long time man fancied he had reached the "ultima thule" of astronomy in these

depths; but the whole idea was changed when it was discovered that beyond Mars there lie the asteroids and the host of bodies in this solar system which we cannot do more than allude to. Then when we consider that this "sun" of ours, which we think so enormous, and which keeps in subjection so many heavenly bodies, and illuminates them; when we reflect that there are in space, and visible, stars many times larger than our ruling star, each a sun, and that our sun would, if put where the great Sirius glows, be but a speck in the firmament, and his system invisible to our eyes, we may well wonder at the magnitude of the subject, and the Infinite Wisdom and Power "that telleth the number of the stars, and calleth them all by their names."

How to read the Sky.

A few particulars, to enable a reader to identify the most prominent stars may be given as starting-points from which some few excursions into the spangled heavens may be attempted. But the suggestions must be considered with reference to the ever-varying directions of the supposed lines in consequence of the daily revolution of the sphere. We have illustrated this in the cut in the margin, wherein the Lesser Bear is shown as swinging round the Polar Star in different positions. Sometimes the lines of direction



The "Swing" of the Lesser Bear.

will be vertical, sometimes inclined, but all retaining their relative positions.

We have already learnt that the "pointers" of the Great Bear indicate the Polar Star in the Lesser Bear, and we can (roughly) estimate the distance between the pointers as 5°. This will give us the distance between the pointers and the Polar Star as 29. By following an imaginary line through the two northern stars of the "Waggon" (the Bear) away from the "horses," we shall find Capella about 50° away.

If we pass from the first star next the waggon of "Charles's Wain" to the Pole Star, and past it, we shall

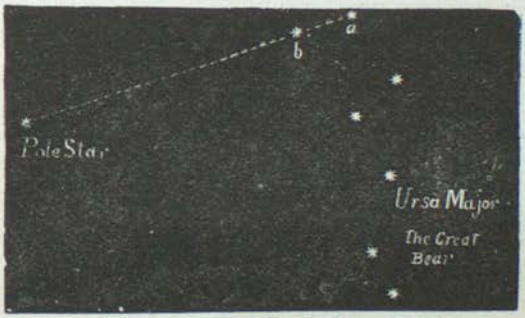


Diagram of the Pole Star.

arrive at an irregular W. This is Cassiopeia, about as far beyond Polaris as the Bear is below it. When the latter is low, the former is at the zenith, and so on.

A line drawn from the Pole Star through the end star of the Great Bear leads to Arcturus. A line taken from Arcturus for about an equal distance will, with the Pole Star, make a triangle with Vega. The Polar Star may be called the Apex of it.

Regulus may be found southwards by drawing a line through the two first stars of the square in the Bear (opposite the pointers). From Vega, almost opposite the Pole Star, and through it about twice as far away on the

other side, is Sirius, a brilliant "sun." Procyon will be found to the westward of Regulus about 30°. From Procyon to the Pole Star a line will pass through Pollux and Castor.

Another line from the pole star through the middle of the three "horses" in the "Wain" will reach Spica Virginis about 70° beyond. So we can describe a large triangle with Spica, Regulus, and Arcturus, at the angles. Regulus is the apex, Spica and Arcturus a short base line.

From the pole star through Capella, passing between Betelgeux and Bellatrix, we shall describe a line leading to the three stars of Orion's belt. Between it and the Pleiades is Aldebaran.

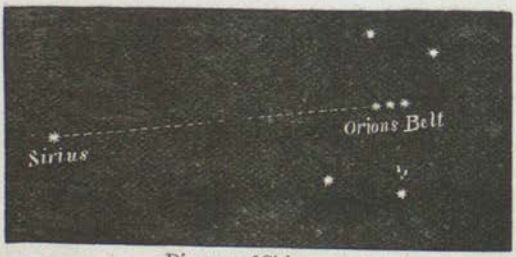


Diagram of Sirius, etc.

There are many other stars which could be indicated; but on a fine evening, if the observer will mark them upon a piece of paper, placing the pole star in the centre, he will be able to add to his star map very rapidly.

In the foregoing chapters of Astronomy we have seen how the earth and other planets move around the sun; we have glanced at the "fixed" stars and their groups, termed the constellations, and have noted the planets and their characteristics, with many other interesting facts. There is yet a great deal to be learnt, and much study will be required with daily (nightly) observations before the young reader will obtain success as a student of astronomy; but there is no study so interesting. We

have seen what a very small portion of the universe is occupied by our solar system, and what a speck our earth is on the plain of creation. We find ourselves on the border-land of the incomprehensible, and we are lost in speculations upon the unseen.



CHAPTER X.—NEW ASTRONOMICAL APPLIANCES.

A CELESTIAL INDICATOR—ASTRONOMICAL OR COSMOGRAPHICAL CLOCK—A SIMPLE GLOBE—A SOLAR CHRONOMETER.

HAVING said something concerning astronomy, we will give a few instructions respecting the instruments not already described, and make some observations, supplementing our directions in the previous chapter, for many people will be glad to learn how to read the evening skies.

On page 148 we have an apparatus which will prove useful to amateurs; it is a sort of celestial indicator by Mauperin, and will facilitate the finding of every star or constellation, when the apparatus has been made ready by pointing the rod, T, in the direction of the object it is desired to view. This rod is mounted upon a rod, S, and is movable upwards or downwards or sideways, and in the last-named movement it will carry with it an indicator, I, which slides over the chart or diagram of the heavens. The two arms of this indicator are always parallel to the plane of the rod, T, no matter in what position they may be on the chart or the inclination of the rod. The extremities of this rod are terminated by an eye-slit, and by a crescent respectively.

When the apparatus is set, all one has to do is to look through the eye aperture, O, and view the star which we have chosen in the centre of the crescent, C. This star

will be found named in the space between the arms of the sliding indicator, I.

It is easy to perform the operation inversely—that is to say, to find in the sky, by means of the sighting-rod, T, the stars we have chosen on the chart between the prongs of the indicator. The chart represents exactly the heavens as we see them, and this new mode is opposed to the manner generally adopted with celestial charts, and is very important, for it obviates the necessity of holding the map above one's head, its face downwards.

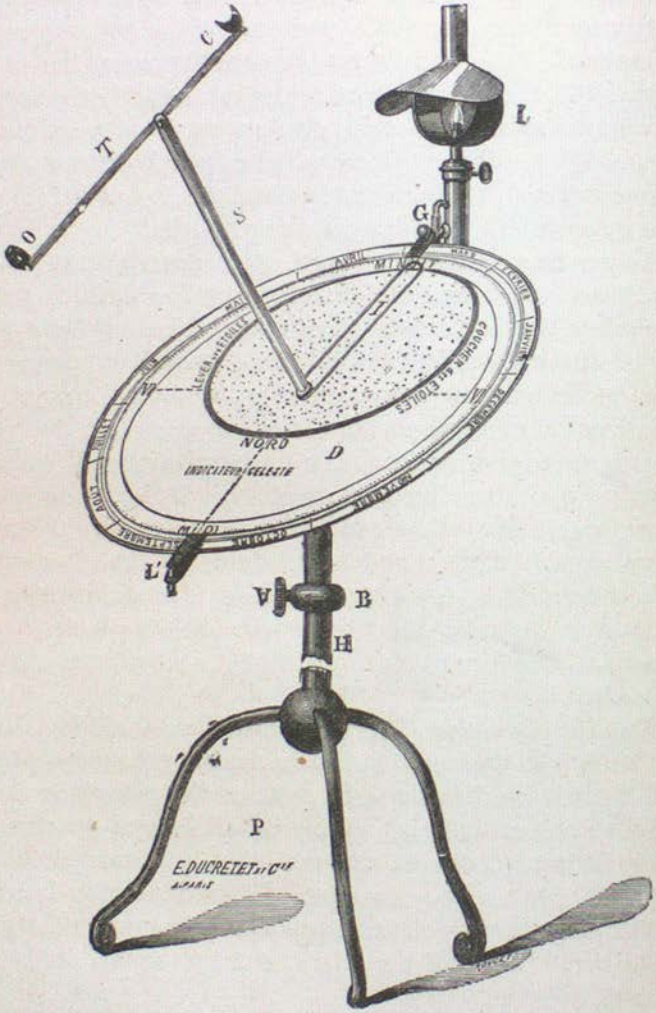
As we have already showed, it is not difficult to find the Polar Star and the Great Bear. The latter is readily recognised by its seven stars, and the Lesser Bear glides around the pole as shown in the diagram on page 144. Now let us see how the celestial indicator will work.

Let us take the apparatus into the open air, and place it upon its tripod stand. The upper portion will be found movable by loosening the screw, V. By another simple arrangement the table can be slanted, and by turning a screw we can entirely slope the side of the chart where midnight (*minuit*) is written. Being placed opposite the polar star we take the upper part of the chart by the button, G, and bring it before us by a horizontal rotative movement.

We now place the sliding indicator upon midday (*midi*), and keep it in that position while working the apparatus—that is, until we have caught sight of the polar star in the centre of the crescent, C, by means of the eye aperture, O. We have now obtained the meridian, and care should be taken to tighten the screw, V. Then the table is raised to its fixed place upon the support; it is regulated according to the latitude of the place, and the apparatus is said to be "oriented."

The upper disc is an elliptical opening, or aperture, which contains for every moment the stars visible upon

the horizon, and the circumference is furnished with a graduated scale of hours divided into five-minute divisions,



Celestial Indicator.

and this is fixed upon the apparatus. The dotted line

between the midday and midnight points gives the meridian.

The disc placed underneath is the celestial chart, on the circumference of which we shall find the days of the months. It can be moved around the rod, S, which represents the axis of the earth around which the heavens are supposed to revolve. When the stars have to be observed, the day of the month has to be brought to the time at which the observation is about to be made. We can easily read off the chart by looking through the eye-piece as already explained. Every five minutes it is necessary to move the chart one division, which indicates that five minutes have passed ; (other stars are, of course, arriving). The apparatus can be packed away when done with, or the bearings taken, and then the trouble of getting it into position again need not be repeated.

A small lamp, L, throws its light upon the chart in such a way that the eyes of the observer are not incommoded, while the table is fully illuminated. It can be placed at L′ if necessary. The inclination varies according to the latitude of the place when the observations are made. There is an arrangement underneath which admits of this inclination according to longitude.

The apparatus can also be made available to ascertain what the aspect of the heavens will be upon any particular evening of the month. We have only to place the chart at the day and hour, and we shall then see upon it all the stars visible above the horizon. We can thus find out at what time the stars rise and set, and those which do not set—to find the hour at which they pass the meridian (the line drawn between midday and midnight upon the chart), and the time of their appearance on the horizon. When the sliding indicator, I, does not show a star that is discoverable in the sky, the observer may conclude that he is viewing a planet. This apparatus is well adapted for

beginners in astronomy, as no deep preparatory study is necessary, and the tyro can read the sky as easily as he could read a book.

A Cosmographical Clock.

We have, in the foregoing chapters upon Astronomy, endeavoured to give the reader some idea respecting the inclination of the earth and its rotation, and writers have often endeavoured to devise an apparatus which shall show the position of the globe in space, its diurnal motion —even its inclination and the succession of seasons in its revolution round the sun. But such reproductions of simultaneous movements have hitherto been obtained only on a very large scale, which find their place well enough in the museum or lecture-room, but which it is quite impossible to utilize in our sitting-rooms, on our tables, or chimney-pieces. Besides, the usual apparatus employed is a very costly one, and only serves for occasional representation; it will not keep the facts constantly before the observer in the manner of a clock showing the time.

But for all who are interested in Astronomy, or in Cosmography, or even for a young person who desires merely to understand the reality of the earth's motion and how our earth is placed in the universe—for any one who deems it of use that he or she should be able to see the signs and the seasons, and the days and years, and how the earth revolves, may obtain an astronomical or cosmographical clock, which will tell him or her how the "world wags"; a useful as well as an ornamental timepiece.

Now this is precisely the result which the talented inventor of the astronomical clock has arrived at. M. Mouret devoted a great portion of his life and all his available means to the realization of his great idea, and, sad to say, he died miserably in an attic the very day before his great and deserving effort brought him the

reward for which he had so painfully striven and devoted himself to by a life of self-denial and labour.

M. Mouret communicated to his globe the astronomical movement, which our earth possesses, by the aid of clock-work, which conveys to it, second by second, at each stroke of the pendulum, the double movement of rotation and progression. The globe turns upon its axis in twenty-four hours, and thus one can perceive, without any mental effort, the rotation of our planet, and the portions of the globe which come under the influence of the sun in rotation, just as they do actually on the earth. Not the least interesting attribute of this ingenious arrangement is the fact that during breakfast or dinner one can see the displacement and revolution of the earth with reference to the sun to all people in the world. Here, on the meridian, all are at midday. There, on the left, near the circle which defines the limit between day and night, the sun is rising and day is beginning ; opposite, on the right, the sun is setting and day is closing. Yonder is the Pacific Ocean in full daylight, while almost every continent is in darkness and the inhabitants wrapped in slumber. Now the Chinese are opening their eyes, and the Asiatic and European con-

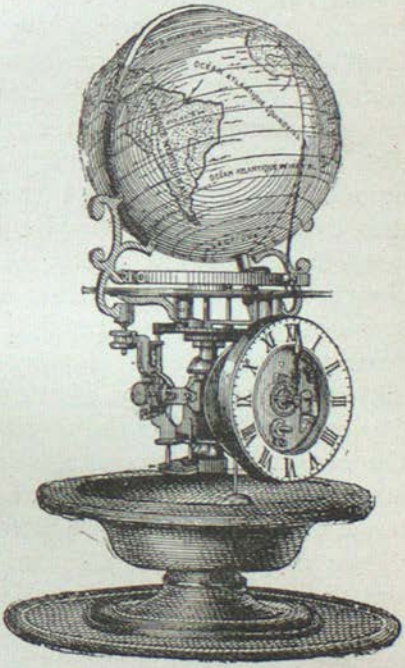


Fig. 633.—Cosmographical clock

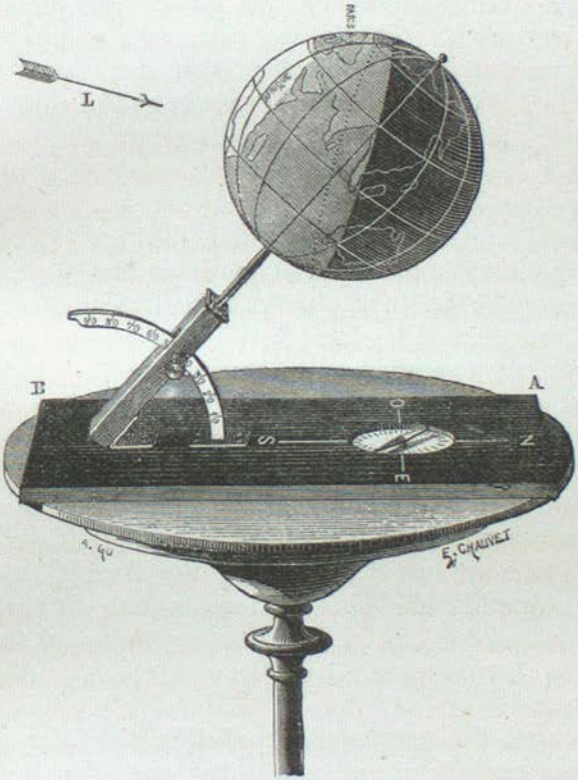
tinents will soon be illuminated and awake. This is the movement of the world as it has ever been since time came into its calculations.

The ingenious inventor, who wished to make a clock of his apparatus, and not being able to change its place on the earth from day to day as the time changed, very cleverly reproduced the sun's movement of declination by making it describe a double cone at the axis of the globe. At the equinoxes the poles are in a plane, and equal day and night are shown. At the winter solstice the north pole is inclined backwards at an angle $23^{\circ}\ 28'$, and our hemisphere is in the winter season. We have then only eight hours' daylight and sixteen of darkness; six months later the pole is inclined towards the sun, and the southern pole is plunged in darkness. We have the long days and the southerners the long nights. An upright dial shows the time of the country in which the globe may happen to be, and one can ascertain at any moment what time it is anywhere else. A horizontal dial indicates the day of the month, and changes every day in a manner corresponding with the movement of the earth around the sun, reproduced by means of the arrangement with the double cone. The spectator is supposed to be turning his back to the sun.

We may add that these movements are all self-acting, and there is no need to interfere with the clock, which is wound up like ordinary timepieces. By an ingenious forethought the inventor provided that the sphere should be independent of the other movements, and it can be used for demonstration in the hands of the lecturer, and be explained with all its motions without in any way disarranging the clock-work. The globe must, of course, when replaced, be put exactly at the correct day and hour.

A Simple Terrestrial Globe.

A terrestrial globe without any mechanism, so long as its axis is parallel to that of the earth, *exposed to the direct rays of the sun*, represents our planet with its recurrence of day and night.



A simple terrestrial globe.

The figure above shows us a globe without any support. The axis is north and south, and makes, with the horizon, an angle equal to the latitude of Paris, if the support, AB, be horizontal. To make the axis of the globe

parallel to the axis of our earth, the line, NS, must correspond to the meridian of the place; this can be done with the compass, for instance.

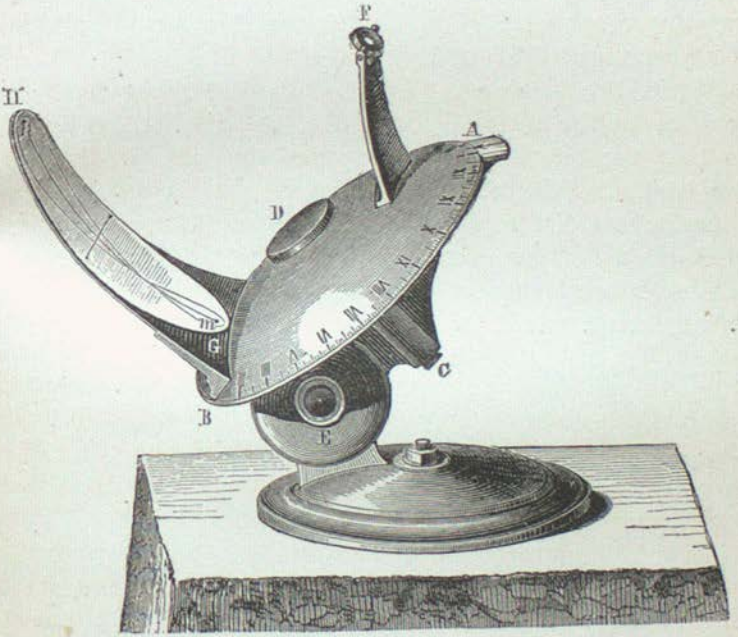
The solar rays always illuminate one-half of a sphere, no matter what its dimensions. If we look at the illustration we shall see that the line of separation between the light and dark portions of the globe corresponds with that in our earth. This globe, then, tells us the passage of light and darkness for the day, and even for the moment of the day, when it is turned as the earth moves. The place examined should be placed in the meridian of that place (Paris, for instance), and occupy the most elevated spot on the globe. The earth is then in just the same position, and daylight and darkness are shown exactly as they exist on the earth at the time.

If this globe be then observed for a few minutes, the sun will be seen rising and setting, as it were, in various places (we must remember we have concentrated the *sun's* rays, not a lamp, upon the globe). The places on the right, if the observer be placed facing the sun, will come out of the shade, and those on the left will enter it. The former are then really enjoying the sunrise, and the others are actually witnessing his setting.

The globe represented, making the double revolution of our planet in the year, will reproduce all the actual phenomena of day and night as taking place on the earth itself if we stand at a little distance so as to observe it all at once.

Of course, the employment of this simple apparatus should not exclude more complicated ones, for the former can only be used on a fine bright day. But the advantage claimed for it is that in it we can imitate nature exactly. Illuminated, as it is, by the real sun, the portions of light and shade are indicated by the rays and not by a metallic circle.

In order that the line of demarcation may be exactly defined, it will be necessary that the sun's rays be concentrated upon the globe, and that no lateral or vertical light be admitted. The curtains should therefore be so arranged, and the blinds pulled down to a certain point, and if the stand or support be painted black it will be



Solar chronometer.

found an advantage. If the globe be a small one, it will be sufficient to place the stand upon an ordinary table, without verifying the horizontal plane. With a large globe the arrangement must be very exact.

A Solar Chronometer.

M. Flechet's chronometer, of which we give an illustration, is a kind of equitorial reduced to its most simple

form. It is possible to ascertain the exact time by it very easily. It consists of a disc, A B, divided into twenty-four hours and fractions of hours. This disc turns upon itself around an arc, CD, which has a direction parallel to the axis of the world, and can be moved on a joint, E, according to the latitude of the place; F is a lens which can be moved and presented to the sun at any time, forming the centre of a concave and exactly spherical plate represented at GH.

When the instrument is fixed so that the axis, C D, is parallel to the axis of the globe, the disc, AB, is turned so that the centre of the image of the sun, produced by the lens, shall fall at *m*. The real time is found by an examination of the position of the index, A, upon the hour graduations of the disc. A French writer, Ch. Delounay, has mentioned this instrument, and considers it easy of arrangement, exact in time, and very useful.

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